Selection and Use of Indicators to Measure the Habitat Status of Wild Pacific Salmon

Prepared for the Pacific Fisheries Resource Conservation Council by

G.A. Packman & Associates Inc. &
Winsby Environmental Services

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
Initiative #1. Analysis of Recommended Indicators 2
Initiative #2. Provincial Snapshot 3
Initiative #3. Pilot Implementation in Selected Watersheds 3
Develop and Implement Indicators Using an Adaptive Management Approach 4

RÉSUMÉ 5
Initiative n° 1. Analyse des indicateurs recommandés 6
Initiative n° 2. Instantané provincial 7
Initiative n° 3. Mise en œuvre pilote dans des bassins hydrographiques choisis 7
Élaboration et mise en œuvre d'indicateurs à l'aide d'une approche de gestion adaptative 8

1.0 INTRODUCTION 9
1.1 Wild Pacific Salmon Policy 9
1.2 Study Approach 11

2.0 WILD PACIFIC SALMON SPECIES / LIFE HISTORY HABITAT REQUIREMENTS 12
2.1 Overview of Pacific Salmon Life History Stages and Habitat Utilization 12
2.1.1 Chinook salmon (*Oncorhynchus tshawytscha*) 12
2.1.2 Chum salmon (*Oncorhynchus keta*) 15
2.1.3 Coho salmon (*Oncorhynchus kisutch*) 16
2.1.4 Pink salmon (*Oncorhynchus gorbuscha*) 17
2.1.5 Sockeye salmon (*Oncorhynchus nerka*) 18
2.1.6 Summary of Species / Life History Requirements 20
2.2 Conservation Unit—Conceptual Habitat Scoping 20
2.3 Relationship between Pacific Salmon Production and Habitat Condition 21
2.4 Overview of Production Limiting Habitat Characteristics 21

3.0 HABITAT STATUS INDICATORS: CONCEPTS AND PREVIOUS WORK 23
3.1 Previous Activities Related to Development of Salmon Habitat Indicators: Key References 23
3.1.1 Pacific Northwest Salmon Habitat Indicators Work Group 23
3.1.2 Canada-B.C. Fish Habitat Inventory & Information Sharing Working Group 24
3.1.3 Province of British Columbia 24
3.1.4 DFO Wild Pacific Salmon Policy Forum 28
3.1.5 Other Jurisdictions 28
3.2 Definition and Purpose of Habitat Indicators 32
3.3 Framework for Indicator Selection 34
3.3.1 Indicator Selection Model 34
3.3.2 Selection Criteria: Indicator Characteristics 35
3.3.3 Geographic Scale: Application of Indicators at Different Levels 36
3.3.4 Direct versus Indirect Indicators 38

4.0 CANDIDATE INDICATORS OF HABITAT STATUS 39

5.0 DATABASES AND OTHER INFORMATION SOURCES IN BRITISH COLUMBIA 44

6.0 WATERSHED-BASED PROGRAMS RELATED TO SALMON SUSTAINABILITY / RECOVERY 46
- B.C. Watershed-based Fish Sustainability Program 46
- Pacific Salmon Foundation and Pacific Salmon Endowment Fund 46
- Okanagan EMAP Reports 46

7.0 WILD PACIFIC SALMON HABITAT INDICATOR WORKSHOP—SUMMARY OF FINDINGS 47
- Complete Interdisciplinary Analysis 48
- Provincial Snapshot 48
- Pilot Implementation Watersheds 48
- Adaptive Management 49
- Communications 49

8.0 CONCLUSIONS AND RECOMMENDATIONS 50
- Recommended Initiative #1. Confirmation of Recommended Indicators 50
- Recommended Initiative #2. Provincial Snapshot 50
- Recommended Initiative #3. Pilot Implementation in Selected Watersheds 51
- Develop and Implement Indicators Using an Adaptive Management Approach 52

REFERENCES 57

APPENDIX 1. DETAILED INDICATOR PRELIMINARY ANALYSIS 61
- Appendix 1. References 97

APPENDIX 2. PREVIOUSLY ESTABLISHED SUITES OF INDICATORS 98

APPENDIX 3. DATABASE DETAILS 105

APPENDIX 4. EXPERT TECHNICAL WORKSHOP REPORT 109
- Expert Technical Workshop on Wild Pacific Salmon Habitat Indicators 109
- 1.0 Introduction 109
- 2.0 Review of the Information Base 110
  - 2.1 Discussion Surrounding the Information Base 110
- 3.0 Discussion of Indicator Selection and Implementation 115
  - 3.1 Purpose of Habitat Indicators 115
  - 3.2 Types of Habitat Indicators 116
- 4.0 Habitat Indicators: Selection and Implementation Strategy 118
  - 4.1 Process for Indicator Selection 119
  - 4.2 Barriers to Implementation 120
  - 4.3 Development of a Shortlist of Candidate Indicators 120
- 5.0 Comments on Specific Candidate Habitat Indicators 122
- 6.0 Recommended Next Steps 126
- Workshop Report Appendices 129

TABLE OF TABLES

Table 2.1. Summary of Pacific Salmon Habitat use at Different Life Stages (Groot and Margolis 1991; Williams 1989)....14
Table 2.2 Summary of Main Habitat Areas Utilized by Each Pacific Salmon Species....20
Table 4.1 Candidate Indicators of Habitat Status....39
Table 8.1 Recommendations on Indicators for Inclusion and Geographic Scale of Application....53
Table 8.2 Recommended Habitat Indicator Evaluation Criteria....56

EXECUTIVE SUMMARY

G.A. Packman & Associates and Winsby Environmental Services were retained by the Pacific Fisheries Resource Conservation Council (PFRCC) to complete a review of background information relevant to the selection of habitat indicators for wild Pacific salmon, in support of implementing "Canada's Policy for Conservation of Wild Pacific Salmon" (the Wild Pacific Salmon Policy). Results from the review were used to plan and support an expert technical workshop held on November 17, 2005. The purpose of the expert technical workshop was to: receive feedback on the information compiled; build concensus on selection of candidate indicators, information availability and requirements for additional information; and identify feasible next steps to develop indicators further. Following the expert technical workshop, a workshop report was prepared and conclusions and recommendations were developed based on the concensus outcomes from the workshop.

Key findings from the review of background information were that considerable work had already been done in reviewing and identifying wild Pacific salmon habitat indicators. A total of eight (8) rationalized lists of indicators had been compiled and are presented in Appendix 2. There was a great deal of similarity across the lists, with variation arising as a result of the intended purpose and application circumstances of the indicators. From the background information, it was apparent that, while indicator selection had been completed on a number of occasions, implementation had not been so successful.

Indicators had been identified at a number of different geographic scales, including: Ecoregion; Broadscale; Watershed; Reach; Site; and Patch. Indicators were also identified at several levels, including: Ecoregion trend monitoring; Broadscale trend monitoring; Watershed condition/health monitoring; Project monitoring; Habitat restoration monitoring; Scientific investigation; and Sentinel monitoring.

The original focus of the expert technical workshop had been to use the background information base and collective expertise of participants to develop and rationalize a suite of indicators. With the findings from the review of background information, the focus of the expert technical workshop was shifted to consider the process for selecting indicators collectively, in order to build support for programs that would ensure effective implementation. In preparing the background information, and in the workshop, exploring this process included testing it out on a series of recommended indicators (Appendix 1 and Appendix 4—Expert Technical Workshop Report). These indicator selection analyses were not intended to be complete and finalized since it was recognized that collaborative efforts are needed to ultimately complete analyses required to confirm indicator selection.

In light of the background information and as a result of the workshop, a list of recommended indicators was developed, in the form of major categories, indicators and geographic scale of application. The recommended major categories and indicators are:

- Water Quantity
    - Instream Flow
    - Water Abstraction
    - Flow Hydrology
- Water Quality
    - Temperature
    - Chemical—Dissolved Oxygen, pH, TDS, Alkalinity, TSS, Turbidity

    - Chemical—Nutrients, BOD_5
    - Biological—Benthic Macroinvertebrates
    - Biological—Zooplankton, Phytoplankton, Chlorophyll *a*
- Physical Habitat
    - Channel Width / Depth
    - Sediment Loading
    - Substrate—Requires further examination
    - Area of Spawning Habitat
    - Off-channel, Wetland Areas
    - Impediments to Accessibility
    - Large Woody Debris
- Aquatic and Riparian Ecosystems
    - Area, Distribution and Types of Riparian and Wetland Vegetation
- Estuarine Ecosystems
    - Change in Area, Distribution, and Types of Tidal and Submerged Wetlands
    - Index of Biotic Integrity for Estuaries—To be defined
- Ecosystem Biodiversity
    - At Risk Species—To be defined
- Land Use Conversion
    - Land Use/Land Cover Change—potentially inducing effects
    - Road-induced Effects
    - Effects Induced by Land Conversion to Impervious

Three key initiatives were identified as a means to move forward with collaborative wild Pacific salmon indicator confirmation and implementation. These are presented below along with an overarching approach recommendation relating to adaptive management.

Initiative #1. Analysis of Recommended Indicators

Inter-disciplinary groups should undertake a detailed analysis of each recommended indicator against a list of technical and feasibility criteria, synthesizing results from analysis of all indicators into a summary matrix. Evaluation criteria and a format for completing this analysis are presented in the form of worksheets and a list in Table 8.2. In completing this technical analysis, inter-disciplinary groups should involve:

- Scientific specialists in disciplines related to each indicator;
- Program and database managers to ensure that data needs, availability and inter-comparability are addressed are factored into selection decisions;
- Managers from relevant programs that may be collecting data for other purposes;
- First Nations that may be conducting monitoring programs and/or have relevant traditional knowledge; and
- Other potential implementation partners and/or stakeholders that may be appropriate to the indicator.

For those indicators that are to be carried forward for implementation, the multi-disciplinary group should develop a corresponding implementation action plan.

Initiative #2. Provincial Snapshot

For a selection of indicators considered most likely to advance to implementation, undertake a trial examination of federal and provincial databases to determine availability/adequacy of data from these sources to support the indicators.

The intent would be to prepare a "Provincial Snapshot" that would provide a bottom up indication as to how feasible/practical implementation of the indicators might be. Based on the background information review and workshop findings, a sub-set of candidate indicators is recommended for this "Provincial Snapshot" appraisal. Other indicators could be included in a "Provincial Snapshot" depending upon timing of results from the detailed technical/feasibility analysis and possibly stakeholder input.

The databases to support compilation of a "Provincial Snapshot" should include but not be limited to: British Columbia Watersheds Atlas; Fisheries Information Summary System; and the British Columbia Land and Resource Data Warehouse. Preparation of the "Provincial Snapshot" should include effort to gather project management, cost, and effectiveness information in order to inform the indicator selection process.

Initiative #3. Pilot Implementation in Selected Watersheds

A pilot program should be implemented in selected watersheds to test the:

- Availability of data sources;
- Inter-comparability of data;
- Viability of various partnership approaches; and
- Utility of the findings in terms of informing management decisions related to the habitat status of salmon Conservation Units (CUs).

The pilot study should also be used to gather information on levels of effort, professional expertise and costs for implementation on a wider scale. Initiatives to implement indicators on Pilot Watersheds should be designed to effectively gather project management and effectiveness information in order to derive the intended program information benefits from a pilot scale exercise. Therefore, an important first step for the pilot program should be development of a comprehensive study design that includes data collection for both technical and management considerations.

Selection criteria for watersheds, and the number of watersheds to be selected for a pilot program should include consideration of streams being examined as part of existing related programs, such as:

- Watershed-based Fish Sustainability Program;
- Pacific Salmon Foundation Salmon Recovery Program;
- Streams within areas of COSEWIC concern (e.g., Interior coho salmon);
- Other locations were detailed site-specific salmon studies have or are being undertaken (e.g., Carnation Creek; Okanagan River);
- Etc.

Stakeholders should be consulted to determine whether key watersheds being examined as part of other programs should be included. Pilot watershed selection criteria should ensure that:

- Indicator application in various environment types, topographies and CUs is tested;
- Indicator application is tested in relation to a variety of "Pressures";
- The pilot watersheds cover all life stages for all wild Pacific salmon species within the overall scope of the pilot program; and
- Other relevant considerations that may emerge, particularly through consultation with stakeholders.

Participants in the November 17, 2005 workshop agreed that the pilot program addressing all of the above demands would likely include in the order of approximately fifteen (15) watersheds.

Develop and Implement Indicators Using an Adaptive Management Approach

An adaptive management approach should be applied to indicator development and implementation, to enable systematic selection, refinement and implementation of indicators, to maximize the potential for them to be implemented effectively and over an appropriate timeframe. The implementation structure for the approach should define a clear organizational framework, with proper tracking of factors such as objectives, roles and responsibilities, resources, outcomes, lessons learned, and mechanisms for inclusion of other governmental and non-governmental entities in program implementation. The approach should be guided by recognition of the advantages of beginning early on a smaller scale, and adapting and growing as experience among relevant parties is gained. Adaptive management will enable indicator application and support programs to grow at a measured pace and in an appropriate manner to ensure sustainability.

RÉSUMÉ

G.A. Packman & Associates et Winsby Environmental Services ont été choisis par le Conseil pour la conservation des ressources halieutiques du Pacifique (CCRHP) pour examiner des informations concernant la sélection des indicateurs de la qualité des habitats du saumon du Pacifique, dans le cadre de la mise en œuvre de la « Politique nationale du Canada pour la conservation des saumons sauvages du Pacifique » (la Politique concernant le saumon sauvage). Les résultats de cet examen ont été utilisés pour planifier et soutenir un atelier technique qui s'est tenu le 17 novembre 2005. L'objet de cet atelier technique était : de recueillir des commentaires sur les informations compilées; de construire un consensus sur la sélection des indicateurs potentiels, sur la disponibilité des informations et sur le besoin d'informations supplémentaires; d'identifier les étapes suivantes qui permettront de développer plus avant les indicateurs. À la suite de cet atelier technique, un rapport a été préparé et des conclusions ainsi que des recommandations ont été formulées en fonction du consensus obtenu.

L'examen des informations de base a permis de conclure qu'un travail important avait déjà été effectué pour identifier et examiner les indicateurs décrivant l'habitat du saumon du Pacifique. Au total, huit (8) listes rationalisées d'indicateurs ont été compilées et sont présentées dans l'Appendice 2. Les listes sont très similaires entre elles et ne diffèrent que par la fin prévue et l'application spécifique de chaque indicateur. L'analyse de l'information de base a également permis de conclure que bien que des indicateurs aient été sélectionnés en plusieurs occasions, leur mise en œuvre n'a jamais été un succès complet.

Des indicateurs ont en effet étaient identifiés pour différentes échelles géographiques, notamment : Écorégion; Grande échelle; Bassin hydrographique; Passage; Site; Parcelle. Des indicateurs ont également été identifiés à plusieurs niveaux, notamment : Surveillance de l'évolution des écorégions; Surveillance des évolutions à grande échelle; Surveillance de la condition et de l'état des bassins hydrographiques; Suivi des projets; Suivi de la restauration de l'habitat; Investigation scientifique; Surveillance par sentinelle.

L'atelier technique était axé initialement sur l'utilisation des informations de base et de l'expertise collective des participants pour élaborer et rationaliser une série d'indicateurs. Tenant compte des résultats de l'analyse des informations de base, les responsables de l'atelier ont recentré l'objectif de celui-ci sur une sélection collective des indicateurs de façon à construire un soutien pour des programmes qui en retour devraient permettre de les mettre efficacement en œuvre. Lors de la préparation des informations de base et de l'atelier lui-même, l'exploration de ce processus a consisté à le tester sur une série d'indicateurs recommandés (Appendice 1 et Appendice 4—Rapport de l'atelier technique). Ces analyses de la sélection des indicateurs n'étaient pas censées être complètes et terminées puisqu'il était entendu que des efforts collectifs étaient nécessaires pour les terminer.

À la lumière des informations de base et des résultats de l'atelier, une liste d'indicateurs recommandés a été dressée, sous la forme de catégories principales, d'indicateurs et d'échelles géographiques d'application. Les principales catégories et les indicateurs recommandés sont les suivants :

- Quantité d'eau
    - Débits
    - Prélèvement de l'eau
    - Hydrologie des débits

- Qualité de l'eau
    - Température
    - Produits chimiques—Oxygène dissous, pH, MDT, alcalinité, TSS, turbidité
    - Produits chimiques—Nutriants, DBO_5
    - Entités biologiques—Macroinvertébrés benthiques
    - Entités biologiques—Zooplancton, phytoplancton, chlorophylle *a*
- Habitat physique
    - Largeur et profondeur des voies d'eau
    - Charge sédimentaire
    - Substrat—Nécessite un examen plus poussé
    - Surface des frayères
    - Zones dans le voisinage des cours d'eau, terres humides
    - Obstacles à l'accessibilité
    - Débris ligneux de taille importante
- Écosystèmes aquatiques et ripariens
    - Surface, distribution et type de végétation dans les zones ripariennes et dans les terres humides
- Écosystèmes estuariens
    - Évolution de la surface, distribution et types de terres humides maréales et submergées
    - Indice d'intégrité biotique pour les estuaires—À définir
- Biodiversité des écosystèmes
    - Espèces en péril—À définir
- Réaffectation du sol
    - Changements de l'utilisation des terres et de la couverture terrestre—ayant possiblement des effets
    - Effets dus aux routes
    - Effets dus à la conversion des terres en zones imperméables

Trois initiatives clés ont été identifiées pour aller de l'avant dans le cadre de la confirmation et de la mise en œuvre collectives des indicateurs pour le saumon sauvage du Pacifique. Ces initiatives sont présentées accompagnées d'une recommandation concernant l'approche importante à adopter pour la gestion adaptative.

Initiative n° 1. Analyse des indicateurs recommandés

Il faudrait que des groupes interdisciplinaires entreprennent une évaluation détaillée de chacun des indicateurs recommandés en fonction d'une liste de critères permettant de juger de l'aspect technique et de la faisabilité puis qu'ils résument les résultats obtenus sous la forme d'une matrice. Des critères d'évaluation et un format suggérés pour mener à bien une telle analyse sont présentés dans des chiffriers et la liste du Tableau 8.2 Pour effectuer cette analyse technique, les groupes interdisciplinaires devraient comprendre :

- des scientifiques spécialisés dans des disciplines liées à chaque indicateur;
- des gestionnaires de programme et de bases de données qui s'assureront que les besoins en données, leur disponibilité et leur intercomparabilité sont pris en compte dans les décisions relatives à la sélection;

- des gestionnaires des programmes pertinents dans le cadre desquels des données pourraient être recueillies à d'autres fins;
- des représentants des Premières nations qui pourraient réaliser des programmes de mesures et/ou posséder des connaissances traditionnelles pertinentes; et
- d'autres partenaires potentiels pour la mise en œuvre et/ou des parties intéressées qui pourraient être compétents dans un des domaines couverts par les indicateurs.

Le groupe multidisciplinaire devrait élaborer un plan de mise en œuvre pour les indicateurs retenus.

Initiative n° 2. Instantané provincial

Pour les quelques indicateurs qui seront probablement adoptés, effectuer un examen d'essai de quelques bases de données fédérales et provinciales pour déterminer dans quelle mesure ces données s'avèrent disponibles et adéquates pour soutenir les indicateurs.

L'objectif serait de préparer un « Instantané provincial » qui indiquerait de manière fondamentale dans quelle mesure la mise en œuvre des indicateurs pourrait être faisable. Un sous-ensemble d'indicateurs potentiels est recommandé pour cet « instantané provincial » évaluatif, choisis en fonction des informations de base et des résultats de l'atelier. D'autres indicateurs pourraient être inclus dans un tel « instantané provincial », suivant la date à laquelle seront obtenus les résultats de l'analyse détaillée de l'aspect technique et de la faisabilité et les commentaires éventuels des parties intéressées.

Les bases de données qui sous-tendront la compilation de l'« instantané provincial » devront inclure, sans limitation: Un atlas des bassins hydrographiques de la Colombie-Britannique; Système de synthèse de l'information sur les poissons; et la base de données sur les terres et les ressources de la Colombie-Britannique. La préparation de l'« instantané provincial » doit inclure la collecte d'informations sur la gestion, le coût et l'efficacité du projet afin de documenter au mieux le processus de sélection des indicateurs.

Initiative n° 3. Mise en œuvre pilote dans des bassins hydrographiques choisis

Un programme pilote devrait être mis en œuvre dans des bassins hydrographiques choisis pour tester :

- la disponibilité des sources de données;
- l'intercomparabilité des données;
- la viabilité de diverses approches de partenariat; et
- l'utilité des résultats pour ce qui est de fonder les décisions de mesure liées à l'état de l'habitat dans les unités de conservation (UC).

L'étude pilote devrait également être utilisée pour recueillir des informations sur le niveau des efforts, de l'expertise professionnelle et des coûts liés à une mise en œuvre à plus grande échelle. Toute initiative visant à mettre en œuvre des indicateurs sur des bassins hydrographiques pilotes devrait être conçue pour recueillir le plus efficacement possible des informations sur la gestion et l'efficacité des projets afin de permettre l'évaluation des bénéfices informationnels d'un exercice pilote. Une première étape importante pour le programme pilote devrait donc consister à mettre sur pied une étude détaillée comprenant une collecte de données à des fins à la fois techniques et administratives.

Les critères utilisés pour le choix des bassins hydrographiques et le nombre de bassins devant être choisis pour un programme pilote devraient tenir compte des cours d'eau examinés dans le cadre d'autres programmes en cours, tels que :

- Programme de conservation des poissons par bassin hydrographique;
- Programme du rétablissement du saumon de la Fondation du saumon du Pacifique;
- Cours d'eau situés à l'intérieur de la région couverte par le COSEPAC (p. ex. Saumon coho de l'Intérieur);
- Autres lieux où des études détaillées et spécifiques sur le saumon ont été menées ou sont en cours de réalisation (p. ex. rivière Carnation Creek, rivière Okanagan);
- Etc.

Il est souhaitable de consulter les diverses parties intéressées pour déterminer si certains bassins hydrographiques clés examinés dans le cadre d'autres programmes devraient être inclus. Les critères de sélection des bassins hydrographiques pilotes devraient permettre de faire en sorte que :

- l'application des indicateurs dans plusieurs types d'environnements, de topographies et d'UC puisse être testée;
- l'application des indicateurs soit testée en fonction de diverses « pressions »;
- les bassins hydrographiques pilotes abritent toutes les formes de vie de toutes les espèces de saumon du Pacifique dans le cadre de la portée générale du programme pilote; et
- d'autres considérations pertinentes, pouvant émerger entre autres de consultations avec les parties intéressées, puissent être prises en compte.

Les participants à l'atelier du 17 novembre 2005 ont convenu qu'un programme pilote satisfaisant à toutes les exigences exposées ci-dessus porterait probablement sur environ quinze (15) bassins hydrographiques.

Élaboration et mise en œuvre d'indicateurs à l'aide d'une approche de gestion adaptative

Une approche de gestion adaptative devrait être appliquée à l'élaboration et à la mise en œuvre des indicateurs afin de systématiser leur sélection, leur affinement et leur mise en œuvre, ceci maximisant ultérieurement les chances de mise en œuvre efficace dans un laps de temps approprié. L'approche devrait adopter une structure de mise en œuvre qui définit un cadre organisationnel clair, avec un suivi approprié des facteurs tels que les objectifs, les rôles, les responsabilités, les ressources, les résultats, les leçons apprises et les mécanismes d'inclusion d'autres entités gouvernementales et non gouvernementales dans la mise en œuvre du programme. L'approche devrait être guidée par la reconnaissance des avantages que présente une mise en œuvre précoce à petite échelle et suivie d'une adaptation et d'une croissance au fur et à mesure que les différentes parties gagnent en expérience. La gestion adaptative permettra aux programmes d'application et de soutien des indicateurs de croître régulièrement de manière appropriée afin d'assurer la durabilité.

1.0 INTRODUCTION

The Pacific Fisheries Resource Conservation Council (PFRCC) is an independent Council established to provide advice and information to federal and provincial fisheries ministers and the general public regarding the conservation of Pacific fisheries resources. The Department of Fisheries and Oceans (DFO) released "Canada's Policy for Conservation of Wild Pacific Salmon" (the Wild Pacific Salmon Policy) in June 2005. The PFRCC views the Wild Pacific Salmon Policy as a positive development in the stewardship of Pacific fisheries resources and would like to support and facilitate its successful implementation.

A key component of the Wild Pacific Salmon Policy is the conservation and stewardship of habitat for wild Pacific salmon. In order to focus and support habitat conservation and stewardship efforts, a suite of indicators at a range of scales is needed. This project was intended to assist the PFRCC in providing advice and support to DFO on indicators of the status of Pacific wild salmon habitat. The project was comprised of a background information review and summary, an expert technical workshop and preparation of a final report with recommended action items.

A Background Document was compiled to provide an overview of the state of habitat indicator development for wild Pacific salmon and propose candidate indicators. The overview was used to plan and support a workshop held on November 17, 2005. The purpose of the November 17, 2005 workshop was to:

- Receive feedback on the information compiled; and
- Build concensus on
    - Selection of candidate indicators;
    - Information availability;
    - Requirements for additional information; and
    - Feasible next steps to develop indicators further.

This overall report represents a consolidation of the background information review and workshop findings, along with conclusions and recommended actions.

1.1 Wild Pacific Salmon Policy

The Department of Fisheries and Oceans (DFO) released "Canada's Policy for Conservation of Wild Pacific Salmon" (the Wild Pacific Salmon Policy) in June 2005. The Wild Pacific Salmon Policy provides a blueprint for meeting challenges in the management of wild Pacific salmon. The Policy elaborates clear objectives and strategies to meet them, and presents a decision-making process to ensure wild salmon conservation choices reflect societal values. It is intended that successful implementation of the Policy will provide Canadians with: healthy, diverse and abundant wild Pacific salmon populations for future generations; sustainable fisheries to meet the needs of First Nations and contribute to the current and future prosperity of all Canadians; and improved accounting for ecosystem values in salmon and habitat management decisions.

The Goal of the Policy is to restore and maintain healthy and diverse salmon populations and their habitats for the benefit and enjoyment of Canadians, in perpetuity. The Policy presents four (4) Principles: 1) Conservation; 2) Honour obligations to First Nations; 3) Sustainable Use; and 4) Open Process. There are also three (3) Objectives for achieving the Goal of the Policy: 1) Safeguard genetic diversity of wild Pacific salmon; 2) Maintain habitat ecosystem integrity; and 3) Manage fisheries for sustainable benefits.

A Conservation Unit (CU) management approach is a key concept introduced in the Policy. Under **Policy Objective 1**, there is a statement indicating that DFO intends to maintain diversity through the protection of CUs. A CU is defined as a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to re-colonize naturally within an acceptable timeframe. Action steps are prescribed in the Policy to maintain CUs to the fullest extent possible. Under the Policy, the delineation of CUs is to be based on biological information, including genetic traits, polygenic traits (e.g., run timing, life history traits, ocean distribution), and Aboriginal Traditional Knowledge (ATK). The number of CUs for each species will be a function of available knowledge base and is expected to change over time.

The biological status of a CU will normally be established on the basis of the abundance and distribution of spawners, or proxies. For each CU, higher and lower benchmarks are to be established to delimit Green, Amber and Red status zones. As spawner abundance decreases, a CU would move towards a zone of greater concern, with a corresponding increase in the extent of management intervention. Within a Red zone (highest concern), the level of abundance would not sustain further fish harvesting mortalities or changes in habitat. Status indicators are to be established.

Policy Objective 2 provides for the maintenance of habitat and ecosystem integrity. The Policy indicates that the health and long-term well-being of wild Pacific salmon is inextricably linked to the availability of diverse and productive habitat. The integrity of salmon habitat is challenged by human activities.

The DFO Policy for the Management of Fish Habitat [Habitat Policy] has been guided by the "No Net Loss" (NNL) principle for the protection of fish habitats. Strategies for achieving NNL for wild Pacific salmon have been focused on project-by-project review incorporating mitigation and compensation, mainly in freshwater environments. An ecosystem approach to achieve NNL would be more effective, taking into account productivity limiting habitat characteristics. In evolving to a more integrated approach, DFO intends to make greater use of indicators to assess and monitor habitat health. It is expected that a new focus on the salmon habitat components that are most productive, limiting, or at risk in a CU, will improve decision-making and better link habitat management strategies to harvest and salmon assessment.

Strategy 2 of the Wild Salmon Conservation Policy addresses the need for Assessment of Habitat Status. An overview of important habitats and habitat issues within CUs is to be developed and habitat status will be assessed using indicators that combine scientific and local knowledge, and recognize sensitive life stages and habitats. Indicators are to be selected to reflect overall habitat health. The intent is to track these indicators over time, to assist in habitat planning and management. The assessment of habitat status on the scale of watersheds and CUs will highlight good quality habitat that needs to be maintained and protected, and degraded habitats to be restored or rehabilitated. Action Step 2.1 under the Policy indicates that DFO intends to prepare an overview report for each CU to provide information on key habitats to identify initial priorities for protection, rehabilitation and restoration. DFO will also identify information gaps and factors (e.g., water quality and quantity) that could threaten habitat productivity. Action Step 2.2 indicates that DFO intends to select indicators and develop benchmarks for habitat assessment.

Under the Wild Pacific Salmon Policy, indicators are to be selected on a watershed scale, to assess the quantity and quality of habitats identified in Action Step 2.2. DFO recognizes that indicators may be general across CUs, or selected on a CU and/or habitat type basis. DFO indicates that stakeholders (e.g., government agencies, First Nations governments, watershed planning processes and stewardship groups) will be asked to provide advice on the development or selection of key indicators for their watersheds, based on local knowledge and information on the kinds of data that are available. Benchmarks will be developed to reflect the desired values for key indicators (e.g., temperature for each species). This action step will result in a set of indicators for CUs and benchmarks for the indicators. Under Action Step 2.3 DFO intends to monitor and assess habitat status.

1.2 Study Approach

In completing this study, it was recognized that a number of studies considering indicators in relation to wild Pacific salmon have been conducted relatively recently. Key relevant studies (in chronological order) are listed below and introduced in Section 3:

- Green Mountain Institute (1998)
- Eclipse Environmental Consulting Ltd. (1998)
- Ward (1999)
- Brown and Dick (2001)
- Gustavson and Brown (March, 2002)
- Knight Piésold (April, 2002)
- Oregon Watershed Enhancement Board (OWEB) (2003)
- Dent et al. (2005)
- Tripp et al. (2005)
- Norton-Arnold and Company (2005)

Most of these studies were overview analyses leading to concensus-based outcomes. These studies reflect the latest thinking on indicator development for wild Pacific salmon habitat. For these reasons, these studies were used as primary references, rather than searching out and reviewing the multitude of individual references. For the purposes of referencing, the overview study has been used as the primary reference, and the more specific reference is named but not included in the Reference section of this report.

These studies provide a solid, rationalized foundation for considering indicators for application to habitat of wild Pacific salmon in B.C. Some, however, are focused on one natural resource harvesting sector (i.e., effects of forestry activities on fish sustainability in British Columbia), while others are applicable to the Pacific Northwest of the U.S. To develop habitat indicators for application under the Wild Pacific Salmon Policy, there is a need to review the suite of indicators identified in these studies and: confirm the indicators; add indicators; broaden the application of certain indicators to other situations and habitat pressures; and/or delete indicators from the lists.

In seeking to address these challenges, this overview report presents:

- Information on the habitat requirements of wild Pacific salmon species;
- An overview of recent relevant work that has been done in relation to habitat indicator selection;
- Discussion on approaches that have been applied to select indicators;
- A listing of indicators that have been previously identified;
- Selection of candidate indicators; and
- Analysis for each candidate habitat indicator.

2.0 WILD PACIFIC SALMON SPECIES / LIFE HISTORY HABITAT REQUIREMENTS

2.1 Overview of Pacific Salmon Life History Stages and Habitat Utilization

Use of freshwater and estuarine habitat by Pacific salmon species at different life stages is summarized in Table 2.1. An overview of key habitat considerations related to the CU concept, habitat production and limiting features is provided below.

2.1.1 Chinook salmon (*Oncorhynchus tshawytscha*)

Chinook salmon display highly variable life history traits related to, among other things, distance from spawning areas to the sea, and amount of time spent in freshwater and estuaries/nearshore-coastal areas before migrating to ocean feeding areas (Table 2.1).

Freshwater

Adult chinook salmon spawn in the fall but can be roughly divided into two groups based on the timing of adult migration and location of spawning (Healey 1991). Early migrants ("spring" and "summer" chinook) enter streams in advance of the later migrating "fall" chinook, usually migrating to upper reaches of streams or headwater tributaries of large rivers such as the Fraser and Skeena and holding in freshwater up to six months prior to spawning. In the Fraser system, fall-run chinook generally spawn in lower tributaries such as the Harrison River. Juvenile chinook salmon reside in freshwater for varying lengths of time that also mainly reflect spawning ground distance from the sea. Young of adults that are produced in the upper reaches of streams, mainly from spring- and summer-run adults, usually reside in freshwater for 1–2 years and are referred to as stream-type fry. Young of adults that emerge from spawning areas close to the sea, usually from fall-run adults, migrate relatively rapidly to the sea, usually spending weeks or several months in freshwater and are referred to as "ocean-type" fry, or in the case of fry that move directly to estuaries, "immediate" fry.

Chinook juveniles rear in streams, lakes and beaver ponds, for a few days or weeks, or up to a year or more before they go to sea. Other populations of chinook go directly to estuaries (Roseneau and Angelo, 1999). Some population use lake littoral zone for juvenile rearing (Roseneau and Angelo, 1999).

Estuarine

Adults may be present in estuaries, feeding in deeper water, during the start of upstream migration, which can occur over spring, summer and fall. Adults may hold off stream mouths for several days or weeks before migrating upstream to spawn. The presence in and use of estuaries by young varies considerably mainly by the main types of downstream migrant:

- *Fry migrants ('immediate' fry)* may be present for up to several months in tidal channels of upper deltas;
- *Fingerling migrants ('ocean-type')* generally are found in outer, deeper estuary areas for several months, occasionally year-round; and
- *Yearling migrants ('stream-type')* briefly occupy delta fronts and nearby nearshore areas before moving offshore.

Fry (33–45 mm) utilize shallow, nearshore areas from approximately May to August/September, e.g., tidal channels, tide flats and eelgrass beds, and rear in deeper water as they grow until late summer. Smolts (8–10 cm) migrate to the estuary in July, and rear in outer estuary or deeper nearshore water until fall.

Marine

Stream-type chinook juveniles usually migrate to ocean feeding areas shortly after entering the sea. Ocean-type chinook tend to linger in estuarine and other nearshore areas until the fall before migrating to ocean feeding areas, though some may remain in coastal areas near the natal stream.

Conservation Unit (CU) Concept

Approximately 30 chinook salmon CUs are believed to occur in B.C. and the Yukon, of which six are located in the Fraser River basin (Fisheries and Oceans Canada 2005). Life history differences appear to be more geographically aligned compared to coho, which also have variable life histories, so that the number of CUs is high relative to coho. The 30 CUs encompass a larger number of stocks; 866 stocks have been estimated to occur in British Columbia and the Yukon, of which 17 are considered to be extinct and sixty are at high to moderate risk of extinction or of special concern (Slaney et al. 1996).

Table 2.1. Summary of Pacific Salmon Habitat use at Different Life Stages (Groot and Margolis 1991; Williams 1989)

Species	Adult Upstream Migration	Spawning Habitat	Rearing Habitat		
			Stream	**Lake**	**Estuary/Near-shore Coastal**
Chinook	Spring, summer and fall. Timing varies among populations: *Fall migrants*—usually smaller coastal rivers Spring, summer migrants— Headwaters of large rivers	Varies from small tributaries to main stems of large rivers	Found in small tributaries and larger rivers, usually in areas of moderate water velocity. Residence time varies according to stream-migrant type: *Fry migrants*—usually young of fall-run adults; move seaward shortly after emergence *Fingerling migrants*—up to three months, usually young of fall-run and summer-run adults *Yearling migrants*—usually young of spring and summer run adults	Some lake rearing	*Fry migrants*: up to several months in tidal channels of upper deltas *Fingerling migrants*: generally outer, deeper estuary areas for several months, occasionally year-round *Yearling migrants*: brief occupancy in delta front and nearby nearshore areas before moving offshore
Chum	Summer and fall	Lower reaches of coastal streams and rivers, with exceptions (e.g., in Yukon River chum migrate >2000 km)	Usually migrate to coastal areas immediately after emergence from gravel	Usually no lake rearing	Generally feed in estuaries and shallow nearshore areas for up to several months before moving offshore Usually occupy tidal creeks and sloughs in delta areas
Coho	Summer and fall	Coastal streams to small tributaries of larger rivers	Usually spend one year in streams, often in small channels, with slow-moving shaded areas. Some populations remain for 2–3 years and some migrate as fry	Some populations rear in nearshore littoral areas of lakes	Smolts occupy estuaries during seaward migration and may remain in relatively quiet nearshore coastal areas for up to several months
Pink	Late summer and early fall; dominant run in even or odd years	Tend to spawn closer to sea than other Pacific salmon, with upstream limit often a barrier which other species can surmount	Immediately move to ocean	No lake rearing	Occupy estuaries and shallow nearshore areas for days to several months
Sockeye	Summer and fall. Cyclic dominance cycle, with dominant run every one out of four years	Usually adjacent to lake rearing area. Can include submerged beaches in lakes	Most populations migrate rapidly to nearby lakes for rearing. Some stream-rearing populations	Lake rearing very important for most populations Usually rear for one year, feeding mainly on zooplankton	Smolts move to areas off mouths of natal rivers for periods of several weeks to several months prior to movement into deeper coastal water during migration to ocean areas

Chinook Salmon Production and Habitat Condition

Habitat characteristics that could limit chinook salmon production in freshwater or estuaries varies considerably according to the different life history types and corresponding habitat use that occur among streams along the coast. Human activity believed to have affected chinook production in freshwater includes damming of rivers for hydro-electric power (e.g., Alouette, Coquitlam, Bridge, Nechako rivers in the Fraser River basin and Cheakamus, Puntledge and Cambpell rivers), and in the case of the Nechako River, water withdrawal and re-direction to the Kemano power facility, development in wetlands, land clearing (logging, agriculture, transportation corridors), and agriculture water-withdrawals (Roseneau and Angelo 1999; Walters and Korman 1999). Estuary wetland areas are particularly important for those streams with ocean-type fry.

Initiatives are underway to develop habitat-based methods to estimate production capacity for chinook salmon, particularly in cases where data to support stock-recruit estimates of stock size are weak. Models are being examined that would enable chinook stock size assessment using estimates of spawner capacity in freshwater areas, based on the assumption that freshwater production is limited mainly by spawning habitat. Working reports have been prepared and are under review (e.g., Parken et al. 2002; Thomas 2004).

2.1.2 Chum salmon (*Oncorhynchus keta*)

Chum salmon generally spawn in lower reaches of small to medium sized streams, with newly emergent fry migrating downstream shortly after emergence, and, similar to some populations of chinook salmon, often utilizing estuarine areas prior to commencing migration to ocean feeding areas (Table2.1).

Freshwater

Adult chum salmon spawn in coastal streams and larger rivers (e.g., Fraser and Skeena), in lower reaches of streams, normally not very far inland, though they may migrate up to 100 km from the mouths of larger rivers (Salo 1991). Chum salmon may, however, migrate large distances in some rivers such as the Yukon River where their migration can exceed 2000 km. Chum normally spawn in small to medium sized streams, but in larger rivers they tend to be drawn to groundwater fed side channels. Their tendency to seek out and use groundwater sourced discharges that are somewhat independent of surface flows, means that chum salmon are often able to utilize habitats that other species are not. (Roseneau and Angelo, 1999). This includes backwater sloughs, or highly perturbed areas downstream of dams where normal discharges are severely disrupted. (Roseneau and Angelo, 1999). Fry emerge from gravel in April and May and swim directly to the estuary. Chum salmon fry do not spend very much time in freshwater (Salo 1991; Roseneau and Angelo, 1999).

Estuarine

Adult chum salmon move through estuaries in summer and fall during their upstream migrations. The adults may pause for several days or weeks at stream mouths, depending on discharge, prior to upstream migration, feeding in deeper water. In some areas spawning in estuarine areas may take place.

Generally, chum fry feed in tidal creeks and sloughs in delta areas in estuaries, and shallow nearshore areas for up to several months before moving offshore. Typically, fry school prior to reaching saltwater and rear in shallow, nursery areas near the shoreline; these areas include eelgrass beds, tidal marsh channels and protected bays. As they grow, fry move to deeper water of the outer estuary.

Marine

Chum fry usually begin to migrate to the ocean by late-June and early-July at a size of 8 to 10 cm, usually moving far into the Gulf of Alaska for ocean feeding.

Conservation Unit (CU) Concept

Approximately 15 chum salmon CUs are believed to occur in British Columbia and the Yukon (Fisheries and Oceans Canada 2005). These CUs include a larger number of stocks; Slaney et al. (1996) identify 1,625 chum stocks, of which they consider 22 as extinct and 141 at high risk of extinction. Of the remainder, 23 are at moderate risk of extinction or are of special concern, 966 are unthreatened and 473 have unknown status because no information was available. Generally, chum show few genetic differences between populations and demes compared to other Pacific salmon species (Fisheries and Oceans Canada 2005). The geographical area of most chum CUs will likely be relatively large.

Chum Salmon Production and Habitat Condition

Chum salmon tend to spawn in lowland areas where human activities are generally intense and consequently chum populations have a higher extinction rate than other salmon species (Roseneau and Angelo 1999). Fry in many cases utilize estuaries before going to sea. Also, chum salmon often make use of groundwater-fed areas in locations such as side channels and sloughs that would normally would not have sufficient surface water flow.

Stock abundance assessment is mainly based on visual estimates of escapements and catch data (e.g., Spilsted 2004; Godbout et al. 2004; Ryall et al. 1999).

2.1.3 Coho salmon (*Oncorhynchus kisutch*)

Coho salmon occur in coastal streams and interior watersheds of larger river basins such as the Fraser and Skeena rivers, usually spawning and rearing in very small streams, including tributaries to the larger systems, normally rearing for one year in freshwater though, for some populations this extends to two or three years (Table 2.1).

Freshwater

Adult coho spawn in smaller streams and rivers, migrating to upstream spawning areas from July to November, and spawning from mid-October to mid-December and as late as February (Sandercock 1991). Coho tend to spawn and rear in streams along the coastline, although there are interior populations on both the Skeena and Fraser watersheds. They tend to spawn in smaller tributary streams of larger watersheds (Roseneau and Angelo, 1999).

Typically, fry emerge in April and May, rearing in freshwater for 1–2 years and migrating to estuaries as smolts in May and June. While in freshwater, coho young rear in beaver ponds, small lakes, and small streams with relatively slow moving waters. In lowland areas, streams that have been transformed into drainage ditches sometimes contain large numbers of coho (Roseneau and Angelo, 1999).

Some populations use lake littoral zones for juvenile rearing (Roseneau and Angelo, 1999)

Estuarine

Adult coho salmon move through estuaries at the start of upstream migrations over summer and fall, sometimes pausing for several days or weeks at stream mouths prior to upstream migration, feeding in deeper water.

Smolts occupy estuaries during seaward migration and may remain in relatively quiet nearshore coastal areas for up to several months. Generally, coho smolts do not use the inner estuary for extended periods of time, but may rear in the outer estuary until June or off tidal flats until fall. Fry may rear in the estuary until late September to November, and overwinter in nearshore areas.

Marine

In late summer or fall most juvenile coho migrate to deeper coastal and ocean feeding areas.

Conservation Unit (CU) Concept

Approximately 15 coho salmon CUs are believed to occur in British Columbia and the Yukon (Fisheries and Oceans Canada 2005). Similar to chum, coho show few genetic differences between populations and demes, compared to other Pacific salmon species, but show substantial life history variation within a region. The 15 CUs encompass a much larger number of stocks; Slaney et al. (1996) identify 2,594 coho stocks, of which they describe 29 as extinct, and 214 at high risk of extinction. Of the remainder, 43 are described as being at moderate risk of extinction or are of special concern, 1,024 are unthreatened and 1,284 have unknown status because no information was available. The geographical area of most coho CUs likely will be relatively large and difficult to define. The Interior Fraser River coho population has been assessed as endangered by COSEWIC based on declines in excess of 60% in number of individuals due to changes in freshwater and marine habitats and overexploitation (COSEWIC 2002).

Coho Salmon Production and Habitat Condition

Coho usually spend at least one year in freshwater, mainly in small, slow-flow areas such as pool-areas of small streams, beaver ponds and small lakes. "Coho have probably suffered the most of the salmon species from over-exploitation as well as habitat degradation. Because they are a lowland and small-stream species associated with areas where settlers first developed agriculture and built cities, coho are often the first salmon species to disappear through extinction. In these areas, coho salmon habitat has become homogenized through diking, ditching and channelization, and almost all the important natural-flow patterns and hydrographs, to which this species is subject and adapted to, have been disrupted." (Roseneau and Angelo 1999).

Habitat-based production models are currently being investigated by DFO. These focus on estimates of smolt-production, based on lengths of stream accessible to coho salmon and smolt production per linear length derived from coastwide and index streams (Bockling and Peacock 2004; Thomas 2004). The models are based on the fact that most coho populations rear in freshwater for one year, sometimes two or three years, and habitat production-limits are imposed by sustained periods of low flow over late summer or winter.

2.1.4 Pink salmon (*Oncorhynchus gorbuscha*)

Similar to chum salmon, pink salmon have a simple life history compared to the other salmon species (Heard 1991). Pink salmon spawn in the lower reaches of small to large streams, including the Fraser River mainstem, with emergent fry tending to migrate downstream soon after emergence and, unlike chum salmon, making little use of estuary areas (Table 2.1).

Freshwater

Adult pink salmon spawn in coastal streams and larger rivers, migrate up rivers to spawn in September and October. Runs are characterized by runs in even or odd years, or runs in both years with one of the two being dominant.

Pink fry emerge from spawning gravels from March to May and migrate directly to the estuary.

Estuarine

Adult salmon move through estuaries at the start of upstream migrations over late summer and early fall, sometimes pausing for several days or weeks at stream mouths prior to upstream migration, feeding in deeper water. In some streams, pink salmon spawn in estuaries.

After rapid migration downstream from spawning areas, pink fry occupy estuaries and shallow nearshore areas for days to several months. Fry may remain in tidal channels for several days, but the tendency is to school and rear in shallow (<1m) nearshore waters for 1–2 weeks, rearing in adjacent deeper water as they grow, and migrating from inshore areas to ocean in July.

Marine

Pink salmon fry tend to move quickly through estuary areas, moving immediately northward to ocean feeding areas in the Gulf of Alaska before winter of their first year, returning to spawn in the following fall.

Conservation Unit (CU) Concept

Approximately 25 pink salmon CUs are believed to occur in British Columbia and the Yukon, of which two are located in the Fraser River basin (Fisheries and Oceans Canada 2005). Again similar to chum salmon, pink salmon show few genetic differences between populations and demes compared to other Pacific salmon species. Like other salmon species, the 25 CUs for pink salmon encompass a much larger number of stocks; Slaney et al. (1996) identify 2,169 pink stocks, of which they describe 17 as extinct and 137 at high risk of extinction. Of the remainder, 38 are at moderate risk of extinction or are of special concern, 1,298 are unthreatened and 679 have unknown status because no information was available.

Pink Salmon Production and Habitat Condition

"Pink salmon spawn in a wide range of watershed sizes, from very small streams to the mainstem of the Fraser River. While pink salmon spawning in the larger streams of B.C. seem to have withstood many habitat impacts, many populations in the smaller streams have become extinct. The construction of dams seems to be particularly hard on pink salmon runs. Nevertheless, they are quick to re-colonize areas where they had been extirpated, if given an appropriate opportunity, as demonstrated by the recovery of some pink salmon runs upstream of Hell's Gate on the Fraser River, following the construction of fishways." (Roseneau and Angelo 1999).

Normally, pink salmon do not reside for prolonged periods in either freshwater or estuaries after emergence from spawning gravel. Abundant spawning gravel and relatively stable flows during incubation are the critical determinants for survival and production. Production estimates are normally based on stock-recruitment models (e.g., Cass 2002; Rutherford and Wood 2000).

2.1.5 Sockeye salmon (*Oncorhynchus nerka*)

Sockeye salmon typically spawn in tributaries of lakes found in larger watersheds, with some spawning in groundwater-fed gravel areas of some lakes (Table 2.1). Fry usually migrate to lakes where they normally rear for one year, though some populations may rear in lakes for two or three years (Burgner 1991). Smolts usually migrate quickly to the sea after leaving the rearing lakes, spending little time in estuaries before beginning coastal migration to ocean feeding areas. There are exceptions, however, such as the Pitt and Stikine stocks which rear in rivers.

Freshwater

Typically, mature adults enter natal rivers from June to September, entering spawning areas in lake tributaries, outlets or spring-fed locations along lake shores in September and October. Some populations of sockeye salmon will spawn in lakes, relying upon groundwater flowing through clean gravel to incubate the eggs (Roseneau and Angelo, 1999). Fry emerge in April and May and rear in lakes for 1–2 years. Juveniles from lakes emigrate during April and May as smolts at 60–70 mm. Production within lake nursery environments is constrained by temperature, by nutrients such as nitrogen and phosphorus, by other species of fish that may be competitors or predators, and by basin topography and hydrology (Roseneau and Angelo, 1999). Lakes in warmer and relatively nutrient-rich southern latitudes tend to produce more and larger sockeye smolts as compared to more northerly systems (Roseneau and Angelo, 1999). In northern lakes, fry normally remain an extra year in order to reach a size that is large enough to migrate to the estuary. In some cases, they may stay in the lake for three years. There are rare populations of sockeye that do not require lake rearing. (Roseneau and Angelo, 1999)

Estuarine

Adult sockeye enter estuaries at the start of upstream migrations over summer and fall, where they may pause for several days or weeks prior to upstream migration, feeding in deeper water. At the end of downstream migration, smolts move to areas off the mouths of natal rivers for periods of several weeks to several months prior to movement into deeper coastal water during migration to ocean areas. For some stocks, fry migrate directly downstream and rear in river or upper estuary areas for up to 5 months (until 60–100 mm). Yearlings may also rear in upper estuary areas for up to 6 weeks. Smolts may remain in estuarine waters for two weeks or more, but generally migrate quickly through shallow nearshore to deeper water.

Marine

Sockeye juveniles migrate northward rapidly to rear over their first ocean winter in the Gulf of Alaska, where they may rear for two or more years depending on the stock.

Conservation Unit (CU) Concept

Approximately 100 sockeye salmon CUs are believed to occur in British Columbia, of which 20–25 are located in the Fraser River basin (Fisheries and Oceans Canada 2005). Sockeye are expected to have the greatest number of CUs among Pacific salmon species in British Columbia. Like other salmon species, the 100 CUs for sockeye salmon encompass a much larger number of stocks; Slaney et al. (1996) identify 917 sockeye stocks, of which they describe 20 as extinct and 61 at high risk of extinction. Of the remainder, 3 are at moderate risk of extinction or are of special concern, 463 are unthreatened and 370 have unknown status because no information was available.

Sockeye Salmon Production and Habitat Condition

"Because most sockeye populations tend to spawn and rear in parts of British Columbia that are away from urban centres, many of the habitat impacts affecting other species have not been felt by sockeye. Nevertheless, there have been some large perturbations over the time of the European settlement in British Columbia which have had a significant impact on sockeye production. Perhaps the most notable was the massive rock slide at Hell's Gate on the Fraser River, which impeded the migration pathway of millions of fish for many decades. A joint venture with the United States in the 1930s resulted in fishways being built at this site. This has allowed at least a partial rebuilding of some of the sockeye stocks in the Fraser River.

Habitat impact on the production of sockeye includes the industrial clear-cutting of forests in the watersheds of some of the Fraser River's more productive populations. Of particular concern are the fish in the Stuart and Horsefly Rivers.

Perhaps one of the most overlooked sources of habitat damage has been the lack of adequate escapement, not only to seed the spawning grounds with fertilized eggs, but to provide the all-important micro-nutrients of nitrogen and phosphorus in order to ensure plankton growth in sockeye-rearing lakes. Over the past 20 years, the Department of Fisheries and Oceans has been artificially increasing production of sockeye through lake fertilization. These efforts mitigate some of the losses of nutrients that are no longer available to populations with depressed escapements." (Roseneau and Angelo 1999).

A number of tools are used to estimate sockeye stock abundance, including estimates of freshwater production based on smolt counts at counting fences, usually placed near outlets of lakes, and estimates of lake rearing capacity, based on food production estimates, such as photosynthetic rate data and other potential limiting factors (e.g., Bocking et al. 2002 and Cox-Rogers et al. 2004).

2.1.6 Summary of Species / Life History Requirements

Generalized use of macrohabitat by the five salmon species is summarized in Table 2.2.

Table 2.2 Summary of Main Habitat Areas Utilized by Each Pacific Salmon Species

Species	**Habitat Category**					
	Stream		**Lake**		**Estuary**	
	Spawning	**Rearing**	**Spawning**	**Rearing**	**Delta/tidal channels**	**Other habitat (e.g., eelgrass)**
Chinook	Common	Common	–	Some	Common	Some
Chum	Common	Some	–	–	Common	Some
Coho	Common	Common	–	Common	Some	Some
Pink	Common	Some	–	–	Some	Common
Sockeye	Common	Some	Some	Common	Some	Some

2.2 Conservation Unit—Conceptual Habitat Scoping

The Wild Pacific Salmon Policy bases strategies and action steps on maintaining Pacific salmon diversity through protection of "Conservation Units" (CUs). Under the Policy, a CU is a group of wild salmon sufficiently isolated from other groups that, if extirpated is very unlikely to recolonize naturally within an acceptable timeframe, such as a human lifetime or a specified number of salmon generations. CU numbers and sizes will vary among species, and delineations are expected to change over time as more information and experience is gained.

The intent of action steps related to the Wild Pacific Salmon Policy strategy concerning assessment of habitat status is to select indicators on a *watershed scale* to assess the quantity and quality of the habitats identified in each CU. The initial action step in the strategy will be documentation of habitat characteristics within CUs, identifying habitats that support or limit production in watersheds and CUs. Habitat status will be assessed using indicators that recognize sensitive life stages and habitats.

The components of fish habitat that contribute to the production of fish include provision for: spawning; rearing, migration; and feeding.

In the case of wild Pacific salmon, for certain populations of some species, the habitat components that support these life-history functions may be located geographically close to each other (e.g., Chum salmon utilizing side channels located relatively close to an estuary). In other cases, the essential habitat components supporting a single population of a species may be separated by long distances.

Since each habitat component is needed to produce the population, it is logical to conclude that each component should be included in the habitat definition for a given population, regardless of the distance separating the components.

This means that there will be overlap between the habitat definitions for more than one CU. For example, the estuaries of major rivers such as the Fraser or Skeena rivers will include multiple populations representing multiple species.

From the perspective of selecting habitat indicators to support CU habitat status monitoring, where there is overlap, a logical approach would be to define the habitat requirements and indicators for each CU, to a level of analysis that is effective and practical. Overarching indicators would then be established that monitor the aggregate habitat requirements for the represented Conservation Units.

2.3 Relationship between Pacific Salmon Production and Habitat Condition

Pacific salmon stock abundance has been assessed mainly using methods that involve visual estimates of returning adults, catch data, counts of outmigrating fry and smolts, and stock-recruit models. Habitat-based methods are being examined for chinook, coho and sockeye (Section 2.1).

Chinook

Models are being examined that would enable chinook stock size assessment using estimates of spawner capacity in freshwater areas, based on the assumption that freshwater production is limited mainly by spawning habitat.

Coho

Habitat-based production models currently being investigated by DFO focus on estimates of smolt-production, based on lengths of stream accessible to coho salmon, and smolt production per linear length derived from coastwide and index streams. The models are based on the fact that most coho populations rear for one year, and sometimes two or three years in freshwater and habitat production-limits imposed by sustained periods of low flow over late summer or winter.

Sockeye

A number of tools are used to estimate sockeye stock abundance, including estimates of lake rearing capacity, based on food production estimates, such as photosynthetic rate data and other potential limiting factors.

2.4 Overview of Production Limiting Habitat Characteristics

Pacific salmon species differ greatly in their use of freshwater and estuarine environments (Section 2.1) and, consequently, are subject to production limitations by habitat features that also differ. Limiting factors can include amount of available spawning gravel and amount of juvenile rearing habitat during summer or winter low flow periods. Habitat characteristics and types of human activity that influence production of each species are identified in Section 2.1, and are summarized again below (based mainly on summary material presented in Roseneau and Angelo 1999).

Chinook

Habitat characteristics that could limit chinook salmon production in freshwater or estuaries vary considerably according to the different life history types and corresponding habitat use that occur across streams along the coast. Broad-scale environmental changes and human activity that are believed to have affected chinook production in freshwater includes climate change, geological activity, damming of rivers for hydro-electric power, water withdrawal and re-direction, development in wetlands, land clearing (logging, agriculture, transportation corridors), and agriculture water-withdrawals. Estuary wetland areas are particularly important for those streams with ocean-type fry.

Chum

Chum salmon tend to spawn in lowland areas where human activities are generally intense. Habitat areas susceptible to damage include estuary areas used by fry before going to sea and groundwater-fed areas in locations such as side channels and sloughs.

Coho

Coho usually spend at least one year in freshwater, being mainly found in small, slow-flow areas such as pool-areas of small streams, beaver ponds and small lakes. Effects on coho habitat have included homogenization of habitat through diking, ditching and channelization, and disruption of important natural-flow patterns and hydrographs.

Pink

Pink salmon spawn in a wide range of watershed sizes, from very small streams to the mainstem of the Fraser River, though the amount of time spent in all systems after spawning and egg incubation is small. Factors affecting run sizes have included dams and other impediments.

Sockeye

Sockeye production has been affected by blockages to upstream fish migration and industrial clear-cutting of forests in the watersheds, and limits on plankton growth in sockeye-rearing lakes.

3.0 HABITAT STATUS INDICATORS: CONCEPTS AND PREVIOUS WORK

A considerable amount of work has been done on developing environmental indicators, including habitat indicators, for Pacific salmon. This work has evolved from different jurisdictions relevant to the PFRCC mandate and the DFO Wild Pacific Salmon Policy (e.g., DFO, B.C., Washington and Oregon), and in different human activity sector applications (e.g., forestry, hydroelectric development, integrated watershed management, etc.). Key relevant publications and their context are listed below, followed by an overview of the common elements that are instructive to the process for developing habitat indicators in the context of the DFO Wild Pacific Salmon Policy. Overviews of some of these key papers are provided in Appendix 2 for reference.

3.1 Previous Activities Related to Development of Salmon Habitat Indicators: Key References

3.1.1 Pacific Northwest Salmon Habitat Indicators Work Group

Green Mountain Institute. 1998. Toward "A Small, but Powerful" Set of Regional Salmon Habitat Indicators for the Pacific Northwest. Prepared for the Pacific Northwest Salmon Habitat Indicators Work Group.

The Pacific Northwest Environmental Indicator Work Group (PNEIWG) commissioned the Green Mountain Institute to conduct a process to develop a set of indicators that would be broadly applicable to the geographic area and range of challenges relevant to its membership and focused on salmonid stocks at risk. The PNEIWG was comprised of state agencies from Washington, Oregon, Idaho and Alaska, as well as representatives from the B.C. Ministry of Environment, Lands and Parks, and Environment Canada, Pacific Region. This was a fairly high level exercise that involved identifying suites of indicators, and combining and priority ranking indicators utilizing a voting process. Emerging from this process, was a suite of 21 indicators that formed the basis for "a small, but powerful" set that could become operational on a regional basis. The indicators identified through this process have tended to be central points of departure for other subsequent wild Pacific salmon habitat indicator identification processes. The indicators identified as a result of this process are listed in Appendix 2.

Ward, W.J. 1999. Pacific Northwest Salmon Habitat Indicators—Pilot Project, Snohomish River Basin. Prepared for the Washington State Department of Ecology.

Ward (1999) reported on a test that was conducted on a short list of regional salmon habitat indicators using existing data from a pilot watershed in Washington State. The regional salmon habitat indicators were identified and developed by a workgroup consisting of members from seven Northwest environmental management agencies representing Environment Canada (Pacific and Yukon Region), British Columbia Ministry of Lands and Parks, Washington, Oregon, Idaho, Alaska and the U.S. Environmental Protection Agency.

The work group originally identified 113 candidate salmon habitat indicators for Northwest rivers, which were then pared down to "a small, but powerful" set of 15 indicators. While the Green Mountain Institute report is not specifically referenced, Ward (1999) appears to be a pilot test of the indicators presented in Green Mountain Institute (1998). The indicators tested in this pilot project are listed in Appendix 2.

Several federal, state, local and tribal sources of indicator data were identified. Collected data were analysed to determine their potential usefulness in addressing a specific indicator or a combination of indicators. The analysis also included the development of figures, tables, and maps generated from GIS software.

The report presents a brief description of the information available on each indicator, followed by either a figure showing the indicator on a basin map, or by tables or graphs showing the indicator. In some cases, indicators could not be developed due to data availability or data inter-comparability issues. Several indicators are combined on basin maps to explore the potential relationships among them.

Conclusions were drawn on the potential applicability and utility of the set of 15 indicators.

3.1.2 Canada-B.C. Fish Habitat Inventory & Information Sharing Working Group

Eclipse Environmental Consulting Ltd. 1998. Workshop Report: Salmon Habitat Indicators and Data Sharing Workshop, Institute of Ocean Sciences, Sidney, B.C. April 22–23, 1998. Sponsored by the Fish Habitat Inventory and Information Sharing Working Group, Canada-B.C. Pacific Salmon Fishery Agreement.
Eclipse Environmental Consulting Ltd. (1998) reports on a workshop convened by the Fish Habitat Inventory and Information Sharing Working Group to consider options and priorities for the development of salmon habitat indicators, data sharing and delivery of supporting data for State of the Environment reporting. The workshop was considered to be a first step in the development of salmon habitat indicators to provide a basis for a federal/provincial presentation to the PFRCC. The workshop was organized by DFO and the B.C. Ministry of Environment, Lands and Parks. Criteria for indicator selection were identified as follows:

- Issue Relevance
    - Representative
    - Responsive to change
    - Predictive
- Usefulness
    - Easy to understand
    - Relevant to policy
    - Comparable
    - Associated with a target or threshold
- Data Reliability
    - Scientifically defensible
    - Adequacy of existing data

These criteria were applied in identifying indicators. The indicators identified as a result of this process are listed in Appendix 2.

3.1.3 Province of British Columbia

BC Forest Practices Code and Watershed Restoration Program: B.C.'s Forest Practices Code (FPC) came into effect on June 15, 1995. The Forest Practices Code encompassed: the *Forest Practices Code of British Columbia Act*; regulations and standards; and guidebooks. The previous *Forest Practices Code of British Columbia Act* was replaced with the *Forest and Range Practices Act* in January 2004. FPC guidebooks that contain elements pertinent to fish habitat assessment include:

> B.C. Ministry of Forests. 2001. Watershed assessment procedure guidebook.
> 2nd ed., Version 2.1. Forest Practices Branch, Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.

> B.C. Ministry of Forests. 1996. Channel assessment procedure guidebook. Forest Practices Branch, Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.
>
> B.C. Ministry of Forests. 1995. Riparian Management Area guidebook. 2nd ed., Version 2.1. For. Prac. Br., Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.

From 1994 to 2002 the Crown corporation, Forest Renewal BC, delivered a variety of programs in British Columbia, with funding derived from forest-industry stumpage-fees. The Watershed Restoration Program (WRP) in B.C. was initiated under the provincial Forest Renewal program in 1994, to undertake rehabilitative works to enhance environmental values in watersheds impacted by past forest practices. A number of procedures were prepared to meet the needs of the Forest Practices Code, as part of the WRP initiative. These included guidance on methods to inventory and assess conditions related to fish and fish habitat, such as:

> Hogan, D.L., S.A. Bird, and D.J. Wilford. 1996. Channel conditions and prescription assessment (interim methods). Funded by Forest Renewal BC. Ministry of Environment, Lands and Parks, and Ministry of Forests, Watershed Restoration Program, Watershed Restoration Technical Circular No. 7.
>
> Johnston, N.T., and P.A. Slaney. 1996. Fish habitat assessment procedures. Funded by Forest Renewal BC. Ministry of Environment, Lands and Parks, and Ministry of Forests, Watershed Restoration Program, Watershed Restoration Technical Circular No. 8, with Errata January 1997.
>
> Koning, C.W. 1999. Riparian assessment and prescription procedures. Funded by Forest Renewal BC. Ministry of Environment, Lands and Parks, and Ministry of Forests, Watershed Restoration Program, Watershed Restoration Technical Circular No. 6.
>
> Gaboury, M., and R. Wong. 1999. A framework for conducting effectiveness evaluations of watershed restoration projects. Funded by Forest Renewal BC. Ministry of Environment, Lands and Parks, and Ministry of Forests, Watershed Restoration Program, Watershed Restoration Technical Circular No. 12.

B.C. Watershed-based Fish Sustainability Program: The Watershed-based Fish Sustainability Program (WFSP) stems from the 1997 Canada-British Columbia Agreement on the Management of Pacific Salmon Fishery Issues (BC Ministry of Fisheries, BC Ministry of Environment, Lands and Parks and Fisheries and Oceans Canada 2001—the WFSP guidebook). The WFSP guidebook is intended for use by government agencies and interest-groups involved in protection, restoration and conservation of fish populations and fish habitat in British Columbia. The guidebook provides guidance on use of a four stage process to develop fish sustainability plans in watersheds (the stages are: Stage I—establish regional priorities; Stage II—establish watershed priorities; Stage III—develop a watershed plan; and Stage IV—implement and improve the plan). WFSP protocols have been applied to a selection of B.C. watersheds since 2001.

> BC Ministry of Fisheries, BC Ministry of Environment, Lands and Parks and Fisheries and Oceans Canada. 2001. Watershed-based Fish Sustainability Planning: Conserving B.C. Fish Populations and Their Habitat. A Guidebook for Participants. Co-published by British Columbia Ministry of Fisheries, British Columbia Ministry of Environment, Lands and Parks, and Fisheries and Oceans Canada. 85p.

Brown, D. and J. Dick. 2001. Environmental Monitoring: Business and Information Needs Study. Daryl Brown and Associates Inc. and Sustainable Visions.
Brown and Dick (2001) reported on a review of environmental monitoring conducted for the Land Information and Inventory Coordinating Committee of the Province of British Columbia. The study findings were based on interviews and questionnaire responses involving provincial agency personnel involved in delivering environmental monitoring and inventory programs (i.e., data providers); and those who are involved in activities to interpret environmental monitoring information in support of program requirements and for environmental trends / effectiveness assessment purposes (i.e., data users).

This study was grounded in the Pressure-State-Impact-Response (PSIR) framework for selecting environmental indicators. The importance of a "business driver" (e.g., legislative requirement) to ensuring that a monitoring program is established and supported is emphasized. Indicators, programs and data availability were presented in the context of the PSIR framework.

Gustavson, K. and D. Brown. 2002. Monitoring Land Use Impacts on Fish Sustainability in Forest Environments. Prepared for British Columbia Ministry of Sustainable Resource Management, March 2002.
Gustavson and Brown (2002) define criteria, indicators, data sources, and data collection methods for examining land use impacts on fish and fish habitat in forest environments. The report addresses a range of anadromous and resident freshwater species, including salmonids, as well as species at risk. Gustavson and Brown (2002) elaborate a framework for indicator selection, drawing upon work from a number of sources. The study involved: 1) reviewing accomplishments to date; 2) proposing appropriate indicators; 3) conducting a consultation workshop; and 4) making final recommendations to define criteria, indicators, and methods, as well as developing a guide for decision-making. A consultation workshop that was conducted included representatives from: Department of Fisheries and Oceans; B.C. Ministry of Forests; B.C. Ministry of Water, Land and Air Protection; B.C. Ministry of Sustainable Resource Management; and Knight Piésold Consulting. The preferred properties of candidate indicators are listed in the report. These properties were:

- Existence of a theoretical or empirical link between the indicator and ecosystem characteristics of interest.
- Known or theoretical linkages to management performance (for necessary attribution of credit to management strategies—i.e., relates to business drivers).
- Information and data availability, including ease of measurement, feasibility and cost-effectiveness of collection.
- Information and data quality, including:
    - Use of appropriate collection and analysis methods;
    - Data accuracy, precision and robustness; and
    - Timeliness and completeness of the records.
- Ease of interpretation and meeting of analysis needs, including the availability of rigorous assessment methods that may need to consider:
    - Known or anticipated sensitivity of the indicator to undesirable changes;
    - Adequacy/appropriateness of the time series and/or coverage available; and
    - Ability of the indicator to meet statistical analysis and modeling needs.

The focus of Gustavson and Brown (2002) is on aquatic ecosystems relevant to forest harvesting.

Knight Piésold Consulting. 2002. Indicators of Fish Sustainability: Managed and Rare Fish in Forest Environments. Prepared for British Columbia Ministry of Sustainable Resource Management, April 2002.
Knight Piésold (2002) presents the results from a review of fish and fish habitat sustainability indicators for status and trend monitoring of managed, rare and non-commercial fish with respect to forest environments. Objectives of the project were to:

- Review and evaluate fish and fish habitat indicators; and
- Recommend a suite of proposed indicators (i.e., tool-kit) that can be used for monitoring of fisheries resources and sustainability.

Knight Piésold (2002) focused on:

- Forest ecosystems, as opposed to urban or agricultural areas;
- Indicators for freshwater ecosystems only (i.e., lakes, stream and rivers); and
- Indicators and indices of fish and fish habitat status, as opposed to indicators or indices of land use, or other anthropogenic stresses (e.g., estimated clearcut area, number of angling licences issued, number of road crossings, number of permitted discharges).

Fish sustainability indicators were recommended in two tiers:

- Tier I indicators were defined as "ready for use" relevant and sensitive indicators for which extensive B.C. data exist for some species, regions, or environments. Tier I habitat indicators included: Temperature; Instream Flow; Physical Habitat (habitat indicators or variables recorded as part of Channel Assessment Procedures (CAP) and/or provided in the B.C. Watershed Atlas); Chlorophyll a for lakes; and Nutrients for lakes; and
- Tier II indicators were defined as relevant, sensitive, and useful indicators for which existing data are limited. Tier II habitat indicators included: Benthic Macroinvertebrates. Some analyses of existing data may be possible, but for the most part, the Tier II indicators would be targets for future development (i.e., through pilot programs) and eventual wide-scale use.

Tripp, D.B., P.J. Tschaplinski, S.A. Bird and D.L. Hogan. 2005. Protocol for Evaluating the Condition of Stream and Riparian Management Areas. FRPA Resources Evaluation Program, B.C. Min. For. And B.C. Min. Water, Land and Air Protection. Victoria, B.C.
Tripp et al. (2005) provide background information and instructions on data collection for riparian-fish Resource Stewardship Monitoring of the BC Ministry of Forests *Forest and Range Practices Act* (FRPA) Resource Evaluation Program. The established goal of monitoring stream channel condition and adjacent riparian management areas was to determine whether FRPA standards and practices governed by regulation are achieving the desired result of protecting fish values by maintaining channel and riparian functions. A list of the indicators used for riparian and stream channel monitoring in relation to forest practices is presented. This report provides an indication of data that are being collected and the degree of guidance provided to the data collection process.

3.1.4 DFO Wild Pacific Salmon Policy Forum

Norton-Arnold & Company. 2005. Wild Pacific Salmon Policy Forum: Summary Report. Submitted to: Department of Fisheries and Oceans, March 28, 2005.

Contributors to this consultation forum on the DFO Wild Pacific Salmon Policy provided the following input related to habitat indicators at a range of geographic scales. It was suggested that the indicators to be used should be meaningful and simple to measure and could include:

- Number of stream crossings
- Percentage of impervious surfaces
- Forest canopy
- Water temperature
- Bank stability
- Woody debris recruitment
- Water quality and quantity
- Minimum stream flow
- Wetlands
- Water flow
- Health of the riparian zone
- Watershed "function"

3.1.5 Other Jurisdictions

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS)

US National Marine Fisheries System 'Matrix': In 1996, The National Marine Fisheries Service (NMFS) drafted a guidance document to assist Pacific Coast states, tribes, and other entities in taking the initiative for coastal salmon restoration (NMFS 1996). The document contains an appendix (Appendix II Making *Endangered Species Act* Determinations of Effect for Individual or Grouped Actions at the Watershed Scale), which presents a matrix of habitat indicators designed to summarize important environmental parameters and levels of condition for each. The matrix is divided into six overall pathways that address the need for indicators that are very location specific, as well as indicators that are geographically broad-scale:

- Water Quality
- Channel Condition and Dynamics
- Habitat Access
- Flow/Hydrology
- Habitat Elements
- Watershed Conditions

The pathways are broken down into "indicators" of two types: (1) Metrics that have associated numeric values (e.g., "six pools per mile"); and (2) descriptions (e.g., "adequate habitat refugia do not exist").

> NMFS. 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle Washington.

U.S. Environmental Protection Agency

Bauer, S.B., and S.C. Ralph. 1999. Aquatic Habitat Indicators and their Application to Water Quality Objectives within the *Clean Water Act*. EPA-910-R-99-014. US Environmental Protection Agency, Region 10, Seattle Wa.

Bauer and Ralph 1999 present a comprehensive review of potentially useful aquatic habitat indicators, based on evaluation of existing habitat parameters used by state and federal agencies in monitoring programs and the habitat variables used as Riparian Management Objectives or as habitat indicators for evaluation of proposed activities under the *Endangered Species Act* (ESA).

They grouped variables that directly measure a habitat characteristic into one of the following categories of aquatic ecosystem components that are fairly location specific in terms of data collection:

- Flow Regime
- Habitat Space and Channel Structure (including LWD)
- Substrate Quality and Size
- Streambank Condition
- Riparian Condition
- Temperature Regime
- Water Quality Constituents
- Habitat Access

US Environmental Protection Agency. Environmental Monitoring and Assessment Program Western Pilot Study. EPA Regions 8, 9, 10.

The Environmental Monitoring and Assessment Program (EMAP) was initiated by EPA's Office of Research and Development (ORD) to estimate the current status and trends of the nation's ecological resources and to examine associations between ecological condition and natural and human disturbances. The goal of EMAP is to develop ecological methods and procedures that advance the science of measuring environmental resources to determine if they are in an acceptable or unacceptable condition. Two major features of EMAP are:

- Use of ecological indicators; and
- Probability-based selection of sample sites.

Regional EMAP (R-EMAP) uses EMAP's indicator concepts and statistical design, and applies them to projects of smaller geographic scale and time frames. R-EMAP provides States and EPA Regional offices opportunities to use EMAP indicators to answer questions of regional interest.

Studies of ecological conditions in streams the Pacific Northwest have been undertaken using EMAP protocols. The following studies include assessment of indicators relevant to Pacific salmon and present general descriptions of the EMAP sample design and indicators:

> Herger, L.G. and G. Hayslip. 2000. Ecological Condition of Streams in the Coast Range Ecoregion of Oregon and Washington. EPA-910-R-00-002. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.
>
> Herger, L.G. and G. Hayslip. 2001. Ecological Condition of Streams in Upper Chehailis Basin Streams. EPA-910-R-01-005. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

> Hayslip, G.A., L.G. Herger, and P. T. Leinenbach. 2004. Ecological Condition of Western Cascades Ecoregion Streams. EPA 910-R-04-005. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

Columbia River Federal Caucus

The Federal Caucus is a group of eight agencies operating in the Columbia River Basin that have natural resource responsibilities related to the *Endangered Species Act* (ESA); the agencies are:

- NOAA Fisheries
- Fish and Wildlife Service
- Bonneville Power Administration
- Army Corps of Engineers
- Bureau of Reclamation
- Environmental Protection Agency
- Forest Service
- Bureau of Land Management

The Caucus has undertaken activities to protect and recover ESA-listed fish in the Columbia River Basin; activities relevant to assessment of salmon habitat, including development of habitat indicators, are described in a series of reports, notably:

> Hillman, T. W. 2004. Monitoring strategy for the upper Columbia basin Draft Report . Prepared for Upper Columbia Regional Technical Team, Upper Columbia Salmon Recovery Board, Wenatchee, Washington.
>
> Johnson, G.E., H. Diefenderfer, T. Berquam, B.D. Ebberts, and J.D. Wilcox. 2003. Research, monitoring and evaluation plan for the Columbia River Estuary and plume. DRAFT. Prepared for NOAA Fisheries by Bonneville Power Administration, US Army Corps of Engineers, Portland District and Pacific Northwest National Laboratory
>
> Jordan, C., J. Geiselman, M. Newsom, and J. Athearn. 2003. Research, Monitoring & Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion Draft 9/11/03
>
> The Federal Caucus. 2000. Conservation of Columbia Basin Fish. Final basinwide salmon recovery strategy. Volumes 1 and 2. Prepared by the Federal caucus which is made up of nine federal agencies

Information regarding habitat indicators and assessment of habitat status is summarized in those reports.

Oregon State

Oregon Watershed Enhancement Board (OWEB). 2003. The Oregon Plan for Salmon and Watersheds: Monitoring Strategy.

The Oregon Plan for Salmon and Watersheds (Oregon Plan), initiated in 1997, is a state-led effort to restore watersheds and recover fish and wildlife populations to productive and sustainable levels, while providing substantial environmental, cultural and economic benefits. The Oregon Watershed Enhancement Board (OWEB) has several key statutory responsibilities, including a requirement to report to the Governor and Legislative Assembly on environmental trends. OWEB (2003) indicates that although a huge volume of data about the environment is available, much of it is so site-specific that it cannot be used to assess the condition of broad geographic regions.

The OWEB proposed a monitoring strategy for salmon in watersheds covered by the Oregon Plan. The objective of the monitoring strategy was to guide development and implementation of specific actions to result in efficient, credible monitoring on the status of watershed conditions and salmon populations. It was intended that, over time, monitoring would track responses to restoration activities within the context of overall trends in watershed condition and species status.

Data categories were developed and the concept of validation watersheds was incorporated. The monitoring and related indicators were to be appropriate for application in Oregon sub-basins and Evolutionary Significant Unit (ESU) regions, at appropriate scales.

Dent, L., H. Salwasser and G. Achterman. 2005. Environmental Indicators for the Oregon Plan for Salmon and Watersheds. Prepared by the Institute for Natural Resources for the Oregon Watershed Enhancement Board.
In order to provide a mechanism to assess Oregon's collective restoration investments, OWEB partnered with the Institute for Natural Resources at Oregon State University to develop and institutionalize a system for tracking a small set of environmental indicators throughout Oregon. The intent is that, ultimately, indicators of environmental condition should support resource management policies and management programs.

Indicators were grouped into four environmental classes:

- Aquatic and Riparian Ecosystems
- Terrestrial Ecosystems
- Estuarine Ecosystems
- Ecosystem Biodiversity

During a November 2003 workshop, technical staff from a range of agencies and organizations specified 15 environmental indicators of basin condition, identifying 5 as an immediate priority.

Dent et al. (2005) indicate that the process used to establish indicators can profoundly affect the likelihood that the proposed indicators will shed light on the questions; will be supported by the collectors, users and stewards of the data; and will successfully inform decision makers. If the process bridges the gaps among scientific, social and political stakeholders, it is more likely to be successful. The integrity of the bridges depends on establishing clear goals, identifying the social values that form the basis of the goal, and seeking and implementing input into the process from representatives of the stakeholder communities in a way that focuses on the values and goals of the project.

In selecting indicators, Dent et al. (2005) identified and focused on six indicator characteristics: Quantifiable; Relevant; Responsive; Understandable; Reliable; Accessible. These are discussed further in Section 3.3.2.

The priority indicators identified were:

- Coldwater Index of Biotic Integrity (combines measures of multiple biological indicators, such as species richness, relative abundance of specific organisms, and health of the organisms)
- Water Quality Index (Temperature, DO, Bacteria, Turbidity, pH, Phosphorus, Nitrogen, Nitrite, Nitrate, Ammonium Nitrate, Macro-invertebrates, BOD, Total Solids)
- Area, distribution and types of riparian and freshwater wetlands vegetation
- Riparian Function (based on vegetation and site capability)

- Condition of physical aquatic habitat and estuarine habitat
- Access to freshwater and estuarine aquatic habitat (km habitat accessible or limited)
- Conformance with instream flow requirements
- Area, distribution and change in area of tidal and submerged wetlands
- Index of Biotic Integrity for estuaries
- At Risk Species (aquatic and estuarine)

Washington State

Smith, C.J. 2005. Salmon Habitat Limiting Factors in Washington State. Washington State Conservation Commission, Olympia, Washington
From 1998 through 2003, salmon habitat Limiting Factors Analysis (LFA) reports were developed for all basins in Washington State that produced salmon or steelhead. Smith 2005 is a summary of 45 individual reports and provides an overview of the results on a state, regional, and watershed scale.

A set of standards to rate salmonid habitat conditions was adopted based on the NMFS 'matrix' (NMFS 1996) and other federal, tribal, and state documents that use some type of habitat rating system. Using the adopted standards, habitat conditions were rated according to three categories for each standard: good, fair, and poor.

The IMW Scientific Oversight Committee. 2004. Evaluating watershed response to land management and restoration actions: intensively monitored watersheds (IMW) progress report. *Submitted to Washington Salmon Recovery Funding Board.*
The IMW Oversight Committee 2004 provides detailed description of features to be measured in intensively monitored watersheds, based on the U.S. Environmental Protection Agency EMAP protocols. Measures to be used for monitoring habitat conditions are described in The IMW Scientific Oversight Committee 2004 are similar to methods outlined in documents listed above for the above US Environmental Protection Agency EMAP.

3.2 Definition and Purpose of Habitat Indicators

When embarking upon an exercise to identify a suite of indicators, it is important to establish a clear and common picture of what an indicator is to be used for.

Eclipse Environmental Consulting Ltd. (1998) reports on a presentation by R. Smith on approaches to environmental indicators. R. Smith grouped the discussion as follows:

Purpose of Environmental Indicators

Decision and Policy-making Tool

- Provide concise and simplified information to facilitate policy development
- Serve as early warning signals to direct attention to priority issues
- Assist in identifying gaps in knowledge

Public Accountability and Awareness

- Improved access to environmental information
- Evaluation of government's environmental performance
- Enhance profile of environmental issues relative to economic and social issues

The definitions from Brown and Dick (2001) for the terms Indicator and Index were re-iterated by Knight Piésold (2002).

Brown and Dick (2001) provide the following guidance with respect to Indicators and Indices and their application.

Indicators and Indices are developed for similar purposes:

- Simplification of complex relationships;
- Selection of the most relevant information for a given management purpose;
- Quantification of information on environmental conditions and trends;
- Communication of information to decision-makers and the public;
- Allocation of financial resources between issues and regions;
- Enforcement of environmental standards; and
- To enhance the efficiency and quality of data collection.

And, they likewise suffer from the same problems and limitations:

- Oversimplification;
- Subjectiveness, both in the assumed representativeness of chosen indicators and in the numerical valuation and weightings associated with indices;
- Loss of information;
- Potential for misuse;
- Inadequate understanding of the underlying cause-effect relationships; and
- Obscuring of important conditions and trends in the individual, aggregate data-sets.

Brown and Dick (2001) clearly differentiate between an Indicator and an Index as follows:

- **Indicator**—a number or other descriptor, measured in real units, which is assumed to be representative of a larger set of conditions or values (e.g., an indicator of biodiversity condition could be the amount or distribution of old forest cover).
- **Index**—values, expressed on a simple numerical (e.g.,1–10, 1–100, 1–200 etc) or descriptive (i.e., low, moderate, high, extreme) scale, which represents a summation of various conditions and measurements across a broad field (e.g., water quality in a particular water body or watershed might be reported on as being excellent, good, fair, borderline or poor, based on a synthesis of various water quality / chemistry parameters such as temperature, dissolved oxygen, nutrients, turbidity, metals, etc.).

Gustavson and Brown (2002) considered indicators to be proxy measures used to determine whether management objectives are being achieved. They indicated that indicators are used for monitoring the effectiveness of approaches to meet management criteria. They considered indicators to be proxy variables for attributes which themselves are difficult if not impossible to measure.

In their report "Environmental Indicators for the Oregon Plan for Salmon and Watersheds", Dent et al. (2005) enunciated the purpose of indicators. The purpose was based on a workshop derived concensus and was to:

- Detect status and trends in environmental resources over time
- Be meaningful at the basin scale
- Be sensitive to management actions
- Inform policy and land management decision makers

Gustavson and Brown (2002) [Verbruggen and Kuik 1991] indicate that the primary function of indicators "…lies in simplification: indicators are a compromise between scientific accuracy and the demand for concise information".

Dent et al. (2005) cite the definition presented in Cairns et al. (1993): "An indicator is a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure."

These are useful considerations to take into account in developing a suite of indicators in support of the DFO Wild Pacific Salmon Policy.

3.3 Framework for Indicator Selection

As noted above, several key reports have been prepared with respect to indicators for salmonids in British Columbia and the U.S. Pacific Northwest. The following represents an integrated overview of key elements from these reports. Although the reports were prepared by different jurisdictions and relate to differing applications, there are many key elements that are common. The following discussion therefore identifies the common elements and highlights differences that arise as a result of differences in intended application.

3.3.1 Indicator Selection Model

In the reports reviewed, two indicator selection models were applied. The most frequently applied model was referred to as the "Pressure-State-Response" model, with minor variations on that title. This model was referred to by Dent et al. (2005), Gustavson and Brown (2002), Brown and Dick (2001), and Green Mountain Institute (1998). Green Mountain Institute (1998) indicated that this is a widely used model.

Brown and Dick (2001) relied on what they termed the Pressure-State-Impact-Response (PSIR) framework for selecting environmental indicators.

Dent et al. (2005) used the Pressure-Condition-Impact-Response conceptual framework for linking indicators with values and goals. This was based on Whitman and Hagan (2003) (Dent et al. 2005 Pg15).

- **Pressure** indicators represent the level of stress related to human activity that affects a value of interest (e.g., area of timber harvest per year)
- **Condition** indicators describe the current condition or status of a resource
- **Impact** indicators signify the change in a value of interest as a result of a pressure
- **Policy Response** indicators show the level of action taken to reduce the pressure on a value of interest.

In substance, the models referred to above are very similar, with slightly different terms being used inter-changeably.

The approach proposed in OWEB (2003) for the Oregon Plan was more of a management approach leading from enunciation of three Desired Outcomes, identification of Framework Questions, and description of nine Implementation Strategies with indicators and monitoring to respond to these.

Knight Piésold (2002) applied a framework adapted from Ecological Risk Assessment (ERA), rather than the PSIR framework used by Brown and Dick (2001). Knight Piésold (2002) considered the PSIR framework to be a more management oriented model, defining response as a management response. Knight Piésold (2002) considered that the PSIR framework is more human and management oriented and includes terrestrial as well as aquatic organisms and ecosystems. Knight Piésold (2002) indicated that, in contrast, the framework it applied is primarily concerned with ecological or environmental impacts on fish and fish habitat (i.e., aquatic ecosystems), and ecological stress-response relationships.

3.3.2 Selection Criteria: Indicator Characteristics

In selecting indicators, as indicated above Dent et al. (2005) focused on six indicator characteristics:

- **Quantifiable:** the indicator can be described numerically and objectively.
- **Relevant:** The indicator will be biologically and socially germane to the questions being asked.
- **Responsive:** The indicator will be sensitive to the stressors of concern.
- **Understandable:** The indicator can be summarized so as to be intuitively meaningful to a wide range of audiences and pertinent decision makers.
- **Reliable:** The indicators will be supported by science. Statistical properties will be well understood and have acceptable levels of accuracy, sensitivity, precision and robustness.
- **Accessible:** Data are available or collection of necessary data is feasible in terms of cost, time and skills.

Dent et al. (2005) also provide a series of references for most lists of indicators from which their list was developed.

Gustavson and Brown (2002) applied the following properties to the selection of candidate indicators for monitoring land use impacts on fish sustainability in forest environments.

- Existence of a theoretical or empirical link between the indicator and ecosystem characteristics of interest.
- Known or theoretical linkages to management performance (for necessary attribution of credit to management strategies—i.e., speaks to the business drivers).
- Information and data availability, including ease of measurement, and feasibility and cost-effectiveness of collection.
- Information and data quality, including:
    - Use of appropriate collection and analysis methods;
    - Data accuracy, precision and robustness; and
    - Timeliness and completeness of records.
- Ease of interpretation and meeting of analysis needs, including availability of rigorous assessment methods that may need to consider:
    - Known or anticipated sensitivity of the indicator to undesirable changes;
    - Adequacy / appropriateness of the time series and / or coverage available; and
    - Ability of the indicator to meet statistical analysis and modeling needs.

Knight Piésold (2002) applied the following evaluation criteria to the identification of habitat indicators.

1. Relevance / Sensitivity

- Is the indicator relevant for aquatic habitats in forest environments?
- Is it sensitive to stressors of concern?

Forest harvest, road construction, grazing and exploitation (managed or sport / commercial species only) were considered the primary stressors of concerns in B.C. forest environments.

2. Costs

- What are the field and laboratory costs for collecting and analyzing samples and data?

3. Data Availability

- Is the indicator currently used in B.C.?
- If so, what is the quantity and quality of data available in B.C.?
- Are there sufficient background data available to interpret values and develop and validate standards?

3.3.3 Geographic Scale: Application of Indicators at Different Levels

Gustavson and Brown (2002) suggest that indicators may be developed and applied at various levels. The report was focused on indicators associated with forestry in B.C. and suggested that indicators at the following levels would be appropriate:

- Watershed Level
- Forest Level
- Regional / Sub-regional Level
- Provincial Level
- National Level

Knight Piésold (2002) suggest that physical habitat and hydrological indicators can be applied at two levels in association with forestry in B.C.:

- Drainage Basin / Reach Level
- Reach to Site / Patch Level

Dent et al. (2005) indicate that monitoring at a basin scale provides a measure of the status or condition of given values and, when implemented over time, can measure changes or trends in those conditions. To establish cause-and-effect relationships requires a scale that differs from broad-scale indicator monitoring. This can be reflected in nested reach- and small-watershed-scale studies. Together, indicator monitoring at the larger basin scale, and effectiveness studies at smaller reach and watershed scales, would provide a complete picture of environmental conditions (Dent et al. 2005).

It is evident from the above discussion that indicators for wild Pacific salmon habitat need to be identified at several different geographic scales and levels of application. These are discussed below in order to clarify terminology for application throughout this report.

In terms of geographic scales of application, the following warrant consideration:

- Ecoregion—indicators that provide insight into important macro-trends that affect all wild Pacific salmon CUs. Indicators at this scale would be relevant to pressures such as climate change or pine beetle de-forestation;

- Broadscale—indicators that are applicable over a number of CUs and/or watersheds but do not necessarily apply at the ecoregion level. Indicators at this scale would be relevant to pressures such as forest fires, forest harvesting, etc.;
- Watershed—indicators that are applicable to a single watershed. Watersheds may encompass one or more CUs; in some cases, CUs may contain more than one watershed, such as small watersheds in close proximity along the coast. It may be possible to extrapolate conclusions drawn from indicators in one watershed to another, provided appropriate inter-comparability validation has been completed. Indicators at this scale would be relevant to pressures such as barriers to migration, reduced flows or forest harvesting;
- Reach—indicators that are applicable to a specific reach that may provide habitat for different species and life stages depending on time of year, flows, cover, substrate, etc. It may be possible to extrapolate conclusions drawn from indicators in one reach to another similar reach within the same watershed or in a different watershed, with appropriate inter-comparability verification. Indicators at this scale would be relevant to pressures such as riparian vegetation removal, sediment release causing gravel embeddedness, etc.;
- Site— indicators that are applicable to a specific site, normally a section/segment of a reach where sampling is conducted and sometimes a location where a project is taking place. It may be possible to extrapolate conclusions drawn from indicators in one site, or for a certain type of project, to another similar site/project combination within the same watershed or in a different watershed, with appropriate inter-comparability verification. Indicators at this scale would be relevant to pressures such as riparian vegetation removal, sediment release causing gravel embeddedness, direct habitat loss (e.g., culvert installation), etc.;
- Patch—indicators that are applicable to a specific patch of habitat, such as an intertidal marsh in an estuary.

In terms of levels of application, the following warrant consideration:

- Ecoregion trend monitoring—results provide a context and interpretive function for findings from indicators applied at the more specific geographic scales;
- Broadscale trend monitoring—results provide a context and interpretive function for findings from indicators applied at the more specific geographic scales, and inform ecoregion trend monitoring conclusions;
- Watershed condition/health monitoring—results provide interpretive function for findings at the project/site level and capture the overriding influences affecting CU production in freshwater and estuarine environments;
- Project monitoring—results are used to determine the extent of productivity loss/gain in association with a project affecting fish habitat;
- Habitat restoration monitoring—results from habitat restoration/improvement projects are used to confirm that objectives in terms of habitat productivity are met;
- Scientific investigation—results are used to indicator provide widely applicable insight into habitat processes and productivity; and
- Sentinel monitoring—results are extrapolated to broader application within a watershed or across a number of watersheds, with appropriate validation of representativeness. This type of monitoring is applicable to indicators that are particularly informative but expensive and/or technically difficult to implement.

The above terminology is used throughout this report.

3.3.4 Direct versus Indirect Indicators

Various definitions are applied with respect to Direct and Indirect indicators. Knight Piésold (2002) defined Direct and Indirect indicators as follows:

- **Direct Indicators:** Measured biological responses of fish communities, populations, and individuals of interest (e.g., fish age distribution, condition factors, density or biomass; and species richness).
- **Indirect Indicators:** Correlates or surrogates of the status or potential productivity of fish populations, communities and fish habitat.

In the context of the DFO Wild Pacific Salmon Policy, the definition for a Direct Indicators provided by Knight Piésold (2002) would apply to the fisheries management aspects of the Policy. Knight Piésold (2002) states that "Many indirect indicators of fish status are direct indicators of fish habitat status".(P41)

For the purposes of developing habitat indicators in support of the Wild Pacific Salmon Policy, it is reasonable to consider Direct Habitat Indicators and Indirect Habitat Indicators as follows:

- **Direct Habitat Indicators:** Direct measures of habitat characteristics (e.g., temperature, dissolved oxygen, substrate, etc.).
- **Indirect Indicators:** Include elements of disturbance to habitat (e.g., amount of land clearing). In essence, these concepts of Direct and Indirect Habitat Indicators are embodied on the Pressure-State-Impact-Response models discussed above.

These are the definitions applied in this report and workshop process.

4.0 CANDIDATE INDICATORS OF HABITAT STATUS

Each of the reports reviewed provided a suite of candidate indicators, usually broken down into categories. The indicators, and the broader categories into which they best fit, are presented below, with references identified. Preliminary detailed analysis of each highlighted indicator is presented in Appendix 1.

Table 4.1 Candidate Indicators of Habitat Status

Indicator Category	Indicator	Geographic Scale of Application	Indicator Type in PSIR Model
Water Quantity (Green Mountain Institute 1998, Ward 1999)	▪ Instream Flow—% of stream miles with instream flow meeting regulatory requirements, seasonal flow requirements for salmonids and/or sufficient to allow salmonid access (Eclipse Environmental 1998, Green Mountain Institute 1998, Ward 1999, Knight Piésold 2002, Gustavson and Brown 2002) ▪ Flow Hydrology—% of waterbodies with minimal, moderate, extreme changes in hydrology from historical patterns (captures low and high flow extremes-deviation) (Green Mountain Institute 1998, Ward 1999, Knight Piésold 2002) ▪ Stream Flow (OWEB 2003)	▪ Watershed ▪ Downstream reach ▪ Conservation Unit	State
Water Quality (Green Mountain Institute 1998, Ward 1999)	▪ Temperature—% of assessed waterbodies where the daily maximum falls into: <10 degrees C—no impairment; 10–15 degrees C—potential impairment to sensitive species; 15–20 degrees C—moderate impairment; >20 degrees C—severe impairment (Green Mountain Institute 1998, Ward 1999, Knight Piésold 2002, Gustavson and Brown 2002, OWEB 2003)	▪ Downstream reach ▪ Watershed ▪ Province/Territory wide ▪ Conservation Unit	State and Impact
Physical Habitat and Hydrology (Knight Piésold 2002)	▪ Channel Width / Depth ▪ Instream flow ▪ Substrate (Knight Piésold 2002)	▪ Site/reach specific ▪ Instream flow can be downstream of a facility or watershed wide	State and Impact

Indicator Category	Indicator	Geographic Scale of Application	Indicator Type in PSIR Model
Physical Habitat (Green Mountain Institute 1998, Ward 1999)	▪ Impediments and Accessibility to Salmon Habitat—# of locations where salmon are impeded, by type, and the amount, by type, of historically anadromous salmonid habitat rendered inaccessible (Green Mountain Institute 1998, Ward 1999, Gustavson and Brown 2002) ▪ Barrier by type (Eclipse Environmental 1998) ▪ Large Woody Debris—Counts of debris pieces with lengths equal or greater than channel widths, noting presence/absence of root wads, per historically anadromous salmonid stream mile (Eclipse Environmental 1998, Green Mountain Institute 1998, Ward 1999, Gustavson and Brown 2002) ▪ Channel Width / Depth (Green Mountain Institute 1998, Ward 1999, Knight Piésold 2002, Gustavson and Brown 2002) ▪ Stream Depth—variance of thalweg depths (Ward 1999, Gustavson and Brown 2002) ▪ Sediment—change in sediment loading rates (Eclipse Environmental 1998, Green Mountain Institute 1998, Ward 1999, Gustavson and Brown 2002) ▪ Spawning Area—% change in spawning areas (Green Mountain Institute 1998, Ward 1999, Gustavson and Brown 2002) ▪ Habitat Type Associated with Water—the amount of habitat, by category (e.g., riparian forest, offchannel, wetland, estuary) associated with the margins of the water course in a watershed and the value of the habitat to the salmonid life-cycle (Green Mountain Institute 1998, Ward 1999) ▪ Riparian condition ▪ Wetland change (OWEB 2003) ▪ Channel bed disturbance ▪ Channel bank disturbance ▪ LWD supply and processes (jams) ▪ Channel morphology ▪ Aquatic connectivity ▪ Fish cover diversity ▪ Fine sediments ▪ Windthrow frequency ▪ Riparian soil disturbance ▪ Shade and microclimate (Tripp et al. 2005)	▪ Watershed ▪ Conservation Unit ▪ Site/reach specific: Most physical habitat indicators are site/reach specific	State and Impact

Indicator Category	Indicator	Geographic Scale of Application	Indicator Type in PSIR Model
Biological Water Quality (Knight Piésold 2002)	▪ Macroinvertebrates ▪ Zooplankton & algae (periphyton, phytoplankton & chlorophyll *a*) (Knight Piésold 2002) ▪ Biological Water Quality Index—% of water rated excellent, good, fair, poor (possible parameters would include fish community and benthic macroinvertebrate species or taxa composition and richness using similar bioassessment protocols (Green Mountain Institute 1998, Ward 1999) ▪ Coldwater Index of Biotic Integrity—combines measures of multiple biological indicators, such as species richness, relative abundance of specific organisms, and health of the organisms) (Dent et al. 2005) ▪ Aquatic invertebrate diversity (Tripp et al. 2005)	▪ Macroinvertebrates and diversity are site/reach specific, being strongly influenced by site specific effects ▪ Biological Water Quality Index and Cold Water Index of Biotic Integrity can be site, reach and/or watershed specific	State and Impact
Chemical Water Quality (Eclipse Environmental Consulting 1998, Green Mountain Institute 1998, Ward, 1999, Knight Piésold 2002)	▪ Temperature ▪ Dissolved oxygen ▪ pH ▪ TDS ▪ Alkalinity ▪ Nutrients (Knight Piésold 2002) ▪ Chemical Water Quality Index—B.C. Water Quality Index and Objectives for Aquatic Organisms (Eclipse Environmental Consulting 1998) ▪ Chemical Water Quality Index—% of waters rated excellent, good, fair, poor (possible parameters would include temperature, dissolved oxygen, biological oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total suspended solids, and bacteria to produce a single number) (Green Mountain Institute 1998, Ward, 1999) ▪ Water Quality Index—estuarine, freshwater and wetlands, % streams rating poor, fair or good (Dent et al. 2005)	▪ Specific parameters are generally more site/reach specific ▪ Parameters that have a widespread influence on aquatic productivity such as nutrients, pH, alkalinity, are applicable at all scales ▪ Indices are generally more broadly applicable at the watershed and Province/Territory scales	State and Impact

Indicator Category	Indicator	Geographic Scale of Application	Indicator Type in PSIR Model
Aquatic and Riparian Ecosystems (Eclipse Environmental Consulting 1998, Dent et al. 2005)	▪ Riparian quality by type (Eclipse Environmental Consulting 1998) ▪ Coldwater Index of Biological Integrity (IBI) for fish and macroinvertebrates ▪ Water Quality Index (WQI) ▪ Area, distribution and types of riparian and wetland vegetation ▪ Riparian function index based on vegetation and site capability (e.g., large wood recruitment, shade, and nutrient input) and wetland function index based on hydrogeomorphic (HGM) typing ▪ Physical aquatic habitat and estuarine habitat condition ▪ Access to freshwater and estuarine habitat (miles of habitat accessible or limited; further analysed by habitat quality) ▪ Regulatory compliance (Dent et al. 2005) ▪ Moss abundance and condition ▪ Disturbance—increaser plants ▪ Vegetation vigour, form and structure. (Tripp et al. 2005) ▪ Habitat Associated with Water—includes riparian forest (Ward 1999)	▪ Site/reach specific ▪ Watershed scale	State and Impact
Estuarine Ecosystems (Dent et al. 2005)	▪ Area, distribution, type, and change in area of tidal and submerged wetlands ▪ Index of Biotic Integrity for estuaries (Dent et al. 2005)	▪ Estuary wide scale ▪ Watershed scale ▪ Province-wide scale	State and Impact
Ecosystem Biodiversity (Dent et al. 2005)	▪ Number of native plant and animal species and distribution over time ▪ At risk species (aquatic, estuarine, and terrestrial; plant and animal) ▪ Percent of non-native invasive species (Dent et al. 2005)	▪ Watershed scale	Pressure, State and Impact

Indicator Category	Indicator	Geographic Scale of Application	Indicator Type in PSIR Model
Land Use Conversion (Eclipse Environmental Consulting Ltd. 1998, Green Mountain Institute 1998, Ward, 1999, OWEB 2003, Dent et al. 2005)	▪ # of acres in a watershed converted from land use/land cover to other classifications (Eclipse Environmental Consulting Ltd. 1998) ▪ # of acres in a watershed converted from land use/land cover classification (e.g., forestry, agriculture, rural residential, industrial, protected status, etc.) to other land use/land cover types over time with emphasis on floodplain to riparian area ▪ miles of road by type, and road crossings, within one mile of historically anadromous salmonid streams, floodplains, and marine shorelines ▪ % of impervious surface (roads, rooftops, and parking lots) in a watershed (Green Mountain Institute 1998, Ward 1999) ▪ Land use ▪ Land cover ▪ Ecoregion characteristics (OWEB 2003) ▪ Change in land use and land cover (Dent et al. 2005)	▪ Reach scale ▪ Watershed scale ▪ Province/Territory wide scale	Pressure

5.0 DATABASES AND OTHER INFORMATION SOURCES IN BRITISH COLUMBIA

A variety of spatial and non spatial data is available to support the candidate indicators identified for further consideration. For the purposes of this overview the majority of references originate from the Government of British Columbia Interactive Website—Land Information B.C. which contains information on, and links to, a variety of data throughout B.C.

This network includes data on: soils and terrain; vegetation; wildlife; fish and fish habitat; water; and base data. Additional information sources were identified from the reports reviewed: however, the data sets referred to in the reports were for the most part also found through the Land Information B.C. website.

More specific information is available through the Community Mapping Network. The Community Mapping Network is a website developed through a collaborative effort involving a number of federal and provincial government departments, as well as non-governmental organizations. The purpose of the website is to integrate community and government natural resource information using an interactive web-based GIS. There is a variety of interactive atlas's available for viewing on this website, containing valuable information related to the indicators selected. Atlas's presented include:

- Abbotsford Watershed Atlas
- BC Watershed Statistics Atlas
- BC Wetlands Atlas
- Central Coast Watershed Atlas
- Chilliwack River Habitat Atlas
- Community Greenmap
- Comox Valley Project Watershed Society
- Eelgrass Bed Mapping Atlas
- Fraser Basin Council Atlas
- Fraser River Estuary Management Program
- Fraser Valley Regional District Habitat Atlas
- Georgia Basin Habitat Atlas
- ICNRC Stream Observation Mapping Tool
- Invasive Species Atlas of BC
- Kamloops-South Thompson Sustainable Community Atlas
- Ministry of Energy & Mines—Offshore Oil & Gas Map
- Pacific Coastal Resources Atlas for British Columbia
- Regional District of Kootenay Boundary Watershed Atlas
- RSBC's Project Rivershed
- Sensitive Ecosystems Inventory
- Sensitive Habitat Inventory and Mapping (SHIM)
- Shorekeepers Atlas
- Shuswap Lake System and Adams Lake Char and Sockeye Spawning Atlas
- South Coast Cutthroat Atlas
- Southern Gulf Island Atlas

- The Spirit of Georgia Strait Alliance
- Sunshine Coast Habitat Atlas
- Upper Skeena Atlas
- West Coast Vancouver Island Atlas

Information availability through available databases is addressed in the detailed information under each of the candidate indicators presented in Appendix 1. Each database is further described in Appendix 3. In addition to a brief database description, this includes:

- Contact Information;
- Scale;
- Geographic Extent;
- Time Period;
- Update / Maintenance Frequency;
- Cost; and
- Metadata Availability.

Numerous community groups are engaged in local data collection and awareness activities in watersheds throughout BC and the Yukon and provide information that supports the database and mapping initiatives listed above. These include community stewardship and involvement programs of First Nations groups and community volunteer organizations such as the Pacific Streamkeepers, Shorekeepers and Reefkeepers.

Once there is initial agreement on which candidate indicators should be pursued further, then pilot testing of their application would be a logical next step. This was the approach implemented by Ward (1999) for the Snohomish River Basin in Washington State. Ward (1999) found that, in Washington State, gathering detailed information to support indicator application at the watershed level was a challenge, that included data gathering and harmonization dimensions.

Information availability and the applicability of databases and GIS systems is expected to vary considerably by CU. Testing the application of candidate indicators for a specific CU, at the pilot level, would involve testing the application of one or more of the more detailed GIS databases listed above.

6.0 WATERSHED-BASED PROGRAMS RELATED TO SALMON SUSTAINABILITY / RECOVERY

Several watershed-based programs related to wild Pacific salmon habitat and indicators are underway in B.C. Some of these are identified and briefly discussed below.

B.C. Watershed-based Fish Sustainability Program

The Watershed-based Fish Sustainability Program (WFSP) stems from the 1997 Canada-British Columbia Agreement on the Management of Pacific Salmon Fishery Issues (BC Ministry of Fisheries, BC Ministry of Environment, Lands and Parks and Fisheries and Oceans Canada 2001—the WFSP guidebook). The WFSP guidebook is intended for use by government agencies and interest-groups involved in protection, restoration and conservation of fish populations and fish habitat in British Columbia. The guidebook provides guidance on use of a four stage process to develop fish sustainability plans in watersheds (the stages are: Stage I—establish regional priorities; Stage II—establish watershed priorities; Stage III—develop a watershed plan; and Stage IV—implement and improve the plan). WFSP protocols have been applied to a selection of British Columbia watersheds since 2001.

> BC Ministry of Fisheries, BC Ministry of Environment, Lands and Parks and Fisheries and Oceans Canada. 2001. Watershed-based Fish Sustainability Planning: Conserving B.C. Fish Populations and Their Habitat. A Guidebook for Participants. Co-published by British Columbia Ministry of Fisheries, British Columbia Ministry of Environment, Lands and Parks, and Fisheries and Oceans Canada. 85p.

Pacific Salmon Foundation and Pacific Salmon Endowment Fund

The Pacific Salmon Foundation has a watershed-based Strategic Salmon Recovery Program (www.psf.ca), which is based on development of recovery plans that bring together actions aimed at rebuilding Pacific salmon populations. The plans include identification of the current state of salmon and their habitat, biological limits to recovery, local and regional fisheries, and the potential and requirements for recovery. The Pacific Salmon Foundation manages recovery Plans funded by Pacific Salmon Endowment Fund. The fund has focused on targeted watersheds within three main priority regions of the province—the Thompson-Shuswap, Georgia Basin and Central Coast. Watersheds for which recovery plans have been prepared include: Englishman River; Coldwater River; Nimpkish River; Rivers/Smith Inlet; Sakinaw Lake; and Squamish River.

Okanagan EMAP Reports

As part of a comprehensive river basin planning process in the northwest United States, a sub-basin management plan has been prepared for the transboundary Okanagan River (identified as the Okanogan River in Washington State) (Northwest Power and Conservation Council 2004). The management plan contains a detailed monitoring and evaluation program, based on the US EPA EMAP protocols. The management plan includes consideration of fish resources in the Canadian portion of the basin and has included input from the Canadian Okanagan Basin Technical Working Group, which includes participants from the Okanagan Nation Alliance, and federal and provincial agencies. A Baseline Monitoring and Evaluation Program was initiated at a pilot level in 2004, with expansion to include the Canadian portion in 2005.

> Northwest Power and Conservation Council. 2004. The Okanogan Subbasin Management Plan. Northwest Power and Conservation Council, Portland, Oregon.

7.0 WILD PACIFIC SALMON HABITAT INDICATOR WORKSHOP—SUMMARY OF FINDINGS

An expert technical workshop was convened on November 17, 2005, to review the identification and use of habitat indicators for assessment of habitat status for wild Pacific salmon.

In compiling the background information presented in the preceding sections of this report, it became apparent that there have been a number of exercises, in B.C. and the United States Pacific Northwest, to identify lists of habitat indicators for wild Pacific salmon. These exercises have for the most part developed lists of habitat indicators that are very similar. It also became apparent that momentum is frequently lost in attempts to move from indicator identification to implementation.

For these reasons, the focus of the November 17, 2005 workshop was shifted from a detailed review of the background information and technical analysis of specific candidate indicators, to a focus on approaches and process to blend indicator identification with a strategic approach to preparing for successful implementation. Workshop participants supported this shift in focus.

The purpose of the workshop was to:

- Obtain feedback on the background information compiled; and
- Build consensus on
    - Information availability;
    - Approaches to selecting and implementing candidate indicators;
    - Requirements for additional information; and
    - Feasible next steps to develop indicators further and facilitate effective implementation.

A brief summary of the findings is presented here and the full workshop report is presented in Appendix 4.

Overall, workshop participants generally agreed that the Background Document provided an effective overview of the current state of indicator development and implementation for wild Pacific salmon habitat. Participants agreed that there will always be additional information sources and/or references to cite; however, it is unlikely that the overall conclusions would change substantively. Those conclusions being that:

- There is a great deal of commonality in the indicators identified through most initiatives documented in the literature;
- There is little to be gained by continuing to review indicator development processes. It is more productive to begin "doing";
- Most initiatives have faltered between the stage of indicator identification and effective medium to long term implementation; and
- The preferred approach is to work collaboratively with other levels of government, First Nations, and stakeholders, in partnership arrangements where possible, to analyse and rationalise indicators for selection and to implement indicators on an incremental basis using an adaptive management approach.

Participants agreed that steps can and should be taken to move the indicator selection initiative forward. However, participants also recognized that, as indicated by the Background Document, the step between indicator identification and implementation is the critical juncture where habitat indicator initiatives have faltered. In order to minimize the potential for this happening, participants agreed that a strategic approach to selection of wild Pacific salmon habitat indicators should be pursued, in order build organizational and stakeholder receptiveness and support. This would facilitate adoption of the recommended indicators as well as the development and implementation of programs and partnerships required to support them, over the long term. Workshop participants agreed that the following key steps provide a reasoned and sound approach for moving forward.

Complete Interdisciplinary Analysis

Participants agreed that an analysis should be completed for each indicator on a shortlist of candidates against identified criteria. The analysis could be done in a matrix, or using the tables presented in Appendix 1 to this report. Participants also recommended that each indicator be examined by a specialist in a discipline/interest relevant to the indicator and the potential inclusion of data from related data-collection programs (for example, participants identified for consideration: Environment Canada CABIN program, the joint provincial/Nature Conservancy of Canada Ecological Aquatic Units of BC program and Okanagan Nation Alliance EMAP data collection activities). This led to the conclusion that the technical analysis of each indicator should be completed by a group, possibly including stakeholders. Stakeholder inclusion would be particularly relevant for those indicators where it is expected that partnership arrangements would be required in order to ensure successful indicator implementation.

For those indicators that are recommended for adoption, an implementation action plan should be developed by the multi-disciplinary group charged with evaluating the indicator.

Provincial Snapshot

As a complement to the interdisciplinary analysis of candidate indicators, participants agreed that it would be useful to prepare a "Provincial Snapshot" for wild Pacific salmon habitat, using indicators identified in Appendix 1, to the extent possible. Participants felt this exercise would provide a real test as to what can be achieved with available data from existing programs to track habitat indicators in CUs. Some databases were identified that could be used as a starting point for this "Provincial Snapshot", including: the British Columbia Watersheds Atlas; the Fisheries Information Summary System; and the British Columbia Land and Resource Data Warehouse.

Results from this test would help to inform the interdisciplinary analysis discussed above. It was recognized that any initiative to prepare a "Provincial Snapshot" would have to be designed to effectively gather project management and effectiveness information in order to inform future development of the indicator selection process.

Pilot Implementation Watersheds

Participants agreed that implementation of identified indicators through a series of Pilot Watersheds would serve to test the: availability of data; inter-comparability of data; viability of various partnership approaches; and utility of the findings in terms of informing CU management decisions. Participants also agreed that this would help to identify required levels of effort, professional expertise and costs for implementation on a wider scale. It was recognized that any initiative to implement indicators on Pilot Watersheds would have to be designed to effectively gather this project management and effectiveness information in order to derive the intended program management benefits from a pilot scale exercise. The experience from implementing a pilot scale indicator test for the Snohomish River watershed (Ward 1999) was influential in achieving participant consensus on this point. While Ward (1999) was very instructive in terms of challenges and resource requirements, it was considered that the specific findings could not be directly extrapolated to B.C., because jurisdictions, data sources, agencies, etc. are so different.

Participants considered that a pilot program to implement indicators on up to approximately 15 watersheds would be appropriate. There would be a need to test indicator application in various environmental conditions, topographies and CUs, with a variety of "Pressures", and to ensure that all life stages of all wild Pacific salmon species are addressed. Participants agreed that the selection of each Pilot Watershed would need to be effectively rationalized against these considerations and other relevant considerations that may emerge.

Adaptive Management

Establishing a suite of habitat indicators for wild Pacific salmon habitat that will be implemented effectively and over an appropriate timeframe is a significant challenge. The approach to indicator identification and staged implementation outlined above was considered reasonable given past experience and the enormity of the challenge. If implemented effectively, with proper tracking of objectives, roles and responsibilities, resources, outcomes, and lessons learned, etc., this approach will provide a solid basis for adaptive management. There was strong agreement among workshop participants in terms of the soundness of the approach and the advantages of beginning early, on a smaller scale, and adapting and growing as experience among the relevant parties is gained.

Communications

Participants agreed that each of the above steps provides a reasonable vehicle to accomplish concrete progress toward implementation of the habitat tracking aspects of the Wild Pacific Salmon Policy.

This strategy would provide an excellent, solidly rationalized basis for communicating progress, working with First Nations, demonstrating the engagement of partners and working positively with stakeholders. It would provide an effective vehicle for communicating successes, and a defensible basis for communicating the reasons for any setbacks that may arise and developing strategies to address them.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The wild Pacific salmon habitat indicators that were examined in detail during this review (Appendix 1) are recommended for confirmation and implementation and are summarized below in Table 8.1. This table presents a list of indicators with recommendations on geographical scale for application, the need for any further investigation of potential use, or discontinuance from further consideration at this time.

The following recommendations present a reasonable and rationalized approach for identifying a suite of habitat indicators with a view to optimizing the potential for successful implementation.

Recommended Initiative #1. Confirmation of Recommended Indicators

Inter-disciplinary groups should undertake confirmation of each recommended indicator to confirm technical feasibility for implementation. Results from confirmation should be presented in the form of a summary matrix including all recommended indicators. Evaluation criteria and a format for completing this analysis are presented in the form of worksheets in Appendix 1. Suggested evaluation criteria that were tested in the Appendix 1 evaluations are listed in Table 8.2. In completing this confirmation, multi-disciplinary groups should involve:

- Scientific specialists in disciplines related to each indicator;
- Program and database managers to ensure that data needs, availability and inter-comparability are addressed are factored into selection decisions;
- Managers from relevant programs that may be collecting data for other purposes;
- First Nations that may be conducting monitoring programs and/or have relevant traditional knowledge; and
- Other potential implementation partners and/or stakeholders that may be appropriate to the indicator.

For those indicators that are adopted, the multi-disciplinary group should put forward an implementation action plan for the indicator.

Recommended Initiative #2. Provincial Snapshot

For a selection of indicators considered most likely to advance to implementation, undertake a trial examination of federal and provincial databases to determine availability/adequacy of data from these sources to support the indicators. The intent would be to prepare a "Provincial Snapshot" that would provide a bottom up indication as to how feasible/practical implementation of the indicators might be. Based on the background information review and workshop findings (summarized in Table 8.1), the following sub-set of candidate indicators is recommended for this "Provincial Snapshot" appraisal:

- **Water quantity/water quality/physical habitat**
    - Temperature
    - Flow
        - Mean Annual Discharge
        - Water abstraction
    - Phytoplankton, Chlorophyll _a_ in lakes
    - Sediment fate: Turbidity as a surrogate for sediment loading
- **Barriers to fish movement**

- **Land use/Land cover, "Pressure" indicators of potential habitat change**
    - Number of hectares in watershed converted to other land use / land cover type
    - Miles of road by type and road crossings within one kilometre of salmonid streams, floodplains and estuarine shorelines
    - % impervious surface in a watershed

Other indicators in Table 8.1 could be included in a "Provincial Snapshot" depending upon timing of results from the detailed technical/feasibility analysis and possibly stakeholder input.

The databases to support compilation of a "Provincial Snapshot" should include but not be limited to: British Columbia Watersheds Atlas; Fisheries Information Summary System; and the British Columbia Land and Resource Data Warehouse. Preparation of the "Provincial Snapshot" should include effort to gather project management, cost, and effectiveness information in order to inform the indicator selection process.

Recommended Initiative #3. Pilot Implementation in Selected Watersheds

A pilot program should be implemented in selected watersheds to test the:

- Availability of data sources;
- Inter-comparability of data;
- Viability of various partnership approaches; and
- Utility of the findings in terms of informing CU management decisions.

The pilot study should also be used to gather information on levels of effort, professional expertise and costs for implementation on a wider scale. Initiatives to implement indicators on Pilot Watersheds should be designed to effectively gather project management and effectiveness information in order to derive the intended program benefits from a pilot scale exercise. Therefore, an important first step for the pilot program should be development a comprehensive study design that includes data collection for both technical and management considerations.

Selection criteria for watersheds, and the number of watersheds to be selected for a pilot program should include consideration of streams being examined as part of existing related programs, such as:

- Pacific Streamkeepers Federation
- Watershed-based Fish Sustainability Program;
- Pacific Salmon Foundation Salmon Recovery Program;
- Streams within areas of COSEWIC concern (e.g., Interior coho salmon);
- Other locations were detailed site-specific salmon studies have or are being undertaken (e.g., Carnation Creek; Okanagan River);
- Etc.

Stakeholders should be consulted to determine whether key watersheds being examined as part of other programs should be included. Pilot watershed selection criteria should ensure that:

- Indicator application in various environment types, topographies and CUs is tested;
- Indicator application is tested in relation to a variety of "Pressures";
- The pilot watersheds cover all life stages for all wild Pacific salmon species within the overall scope of the pilot program; and

- Other relevant considerations that may emerge, particularly through consultation with stakeholders.

Participants in the November 17, 2005 workshop agreed that the pilot program addressing all of the above demands would likely include in the order of approximately fifteen (15) watersheds.

Develop and Implement Indicators Using an Adaptive Management Approach

An adaptive management approach should be applied to indicator development and implementation, to enable systematic selection, refinement and implementation of indicators, to maximize the potential for them to be implemented effectively and over an appropriate timeframe. The implementation structure for the approach should define a clear organizational framework, with proper tracking of factors such as objectives, roles and responsibilities, resources, outcomes, lessons learned, and mechanisms for inclusion of other governmental and non-governmental entities in program implementation. The approach should be guided by recognition of the advantages of beginning early on a smaller scale, and adapting and growing as experience among relevant parties is gained. Adaptive management will enable indicator application and support programs to grow at a measured pace and in an appropriate manner to ensure sustainability.

Table 8.1 Recommendations on Indicators for Inclusion and Geographic Scale of Application

Indicator Category	Indicator	Descriptions of Possible Features to Examine	Geographic Scale of Application and/or Investigation
Water quantity	*Instream Flow*	Change in mean annual discharge—Number of waterbodies, % of waterbodies, % of particular stream classes meeting flow requirements	**Provincial Snapshot** Broad-scale Sentinel Detailed
	Water Abstraction	Number of water withdrawal operations/activities, location, volume, % of flow	**Provincial Snapshot** Broad-scale Sentinel Detailed
	Flow Hydrology	Changes in the hydrograph and flow volume	Merge with Instream Flow
Water quality	*Temperature*	% of assessed waterbodies where maximum daily temperature causes changes in categories of impairment	**Provincial Snapshot** Broad-scale Sentinel Detailed
	Chemical—dissolved oxygen, pH, TDS, alkalinity, TSS, turbidity	Percent of waters rated excellent, good, fair, poor (parameters would include dissolved oxygen, pH, TDS, Alkalinity, TSS, Turbidity)	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
	Chemical—nutrients (nitrate, nitrite, ammonia, total phosphorous), BOD_5	Percent of waters rated excellent, good, fair, poor (parameters would include Nitrate, Nitrite, Ammonia, Total Phosphorous).	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
	Biological—Benthic macroinvertebrates	Species composition, biomass, percent EPT (Emphemeroptera, Plecoptera, Trichoptera), tolerant versus intolerant species, functional guilds	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
	Biological—zooplankton, phytoplankton, chlorophyll a	Species composition, biomass, indicator species	**Provincial Snapshot** Broad-scale Sentinel Detailed

Indicator Category	Indicator	Descriptions of Possible Features to Examine	Geographic Scale of Application and/or Investigation
Physical habitat	*Channel Width/Depth*	Stream depth: Variance in thalweg depths (thalweg is the flow path of the deepest water in a stream)	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
	Sediment Loading	Surrogate: Turbidity	**Provincial Snapshot** Broad-scale Sentinel Detailed
		Change in sediment loading rates	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
	Substrate	To be examined further	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
	Area of Spawning Habitat	Possibly, % change in spawning area	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
	Off-channel, Wetland Areas	Amount of habitat associated with the water margins of the water course and the value of the habitat to the salmonid life-cycle	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
	Impediments to Accessibility to Salmon Habitat	Number of locations where salmon are impeded, by type of impediment	**Provincial Snapshot** Broad-scale Sentinel Detailed
	Large Woody Debris	Counts of debris pieces of a defined character per historically anadromous stream kilometre	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
Aquatic and riparian ecosystems	*Area, Distribution and Types of Riparian and Wetland Vegetation*	Quantification of area, distribution and types of riparian and wetland vegetation	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis

Indicator Category	Indicator	Descriptions of Possible Features to Examine	Geographic Scale of Application and/or Investigation
Estuarine ecosystems	*Change in Area, Distribution and Types of Tidal and Submerged Wetlands*	Quantification of area, distribution and types of tidal and submerged wetland vegetation, and comparison over time	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
	Index of Biotic Integrity for Estuaries	To be defined	Examine federal, provincial and other potential data-sources for application to streams for use as sentinels and/or detailed study
Ecosystem biodiversity	*At Risk Species*	To be defined	Potential application-scale: Broad-scale Sentinel Detailed Subject to detailed analysis
Land Use Conversion	*Pressure Indicator: Land Use/Land Cover change potentially inducing effects (Emphasis on floodplain to riparian areas)*	Number of Hectares in Watershed Converted to Other Land Use / Land Cover Type	**Provincial Snapshot** Broad-scale Sentinel—as per detailed streams Detailed studies in streams to test assumptions regarding effects of land use/cover change on salmon habitat
	Pressure Indicator: Road-induced Effects	Miles of road by type and road crossings within one kilometre of salmonid streams, floodplains and estuarine shorelines (includes railways)	**Provincial Snapshot** Broad-scale Sentinel—as per detailed streams Detailed studies in streams to test assumptions regarding effects of land use/cover change on salmon habitat
	Pressure Indicator: Effects Induced by Land Conversion to Impervious	% impervious surface (roads, rooftops, and parking lots) in a watershed	**Provincial Snapshot** Broad-scale Sentinel—as per detailed streams Detailed studies in streams to test assumptions regarding effects of land use/cover change on salmon habitat

Table 8.2 Recommended Habitat Indicator Evaluation Criteria

Criterion	Evaluation Considerations
Relevance	▪ Wild Pacific salmon (species and life history stages) and beyond salmon ▪ Policy ▪ Management ▪ First Nations ▪ Public
Scientific validity	▪ There is a link to wild Pacific salmon production (species and life history stages) ▪ Standard methodology, protocols and QA/QC are available ▪ Amendable to statistical analysis ▪ Robust

Input data:
Availability/quality/coverage
	▪ Baseline data are available
	▪ Data are currently available and will be available on a continuing basis through an existing program
	▪ Data medium and format (paper files, reports, electronic, in format that facilitates integration with other data)
	▪ Reliability of the data
	  ▪ Supported by appropriate data collection protocols and QA/QC procedures/documentation
	  ▪ Metadata are available and accessible
	▪ Data are readily accessible
	▪ Robustness
	▪ Reflects both short/longterm response and trends
	▪ Indicator data do not have a lag time that compromises effectiveness and/or utility
	▪ Data are amenable to providing appropriate coverage at the Broad-scale, Sentinel and Detailed Study levels

Applicable scale	▪ Data are available at the appropriate scale (Broad-scale, Sentinel Detailed Study) to provide insight into wild Pacific salmon production at the CU level ▪ Data can support decisions at both the strategic and site specific levels
Status or trend applicability	▪ Timeseries data are available ▪ Database is updated at appropriate time intervals
Data management considerations	▪ A database update process exists and is supported by QA/QC procedures, metadata, etc.
Cost	▪ Data are not inordinately expensive to collect
Overall feasibility	Summary statement providing a rationalized conclusion on overall acceptability.

Note: Indicator evaluation criteria in this table are based on factors considered during initial review of indicators in Appendix 1, and additional criteria/factors suggested for consideration during the workshop (Appendix 4).

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APPENDIX 1. DETAILED INDICATOR PRELIMINARY ANALYSIS

Indicator Category: **Land Use Conversion**

Candidate Indicator: **Number of hectares in watershed converted to other land use / land cover type (Emphasis on floodplain to riparian areas)**

Source for Indicator:
Eclipse Environmental Consulting Ltd. (1998)
Green Mountain Institute (1998)
Ward (1999)
From Gustavson and Brown (2002):
- The Pacific Northwest Salmon Habitat Indicators Work Group (Green Mountain Institute 1998);
- [For Forests:
    - Canadian Council of Forest Ministers (1995);
    - Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000);
    - Innovative Forest Practices Agreement (IFPA).]

OWEB (2003)
Dent et al. (2005)

Indicator Type: Pressure

Indicator Rationale: Change in land use / land cover type in a watershed can have significant effects on hydrology, water quality and food availability, particularly changes in the riparian zone.

Indicator Definition / Overview: Number of Hectares in Watershed Converted to Other Land Use / Land Cover Type (Emphasis on floodplain to riparian areas)

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Eclipse Environmental (1998) noted the following with respect to application:
- Emphasis should be on conversion of flood plains and riparian areas, although the indicator should consider what is happening in the whole watershed.
- The indicator should include both land use and land cover at the same time.
- There is a need to define classifications of conversions, decide on scale, note what the land use is converted to and from what, and to distinguish between spatial and temporal change.

Data Availability / Quality:

The British Columbia Watershed Atlas (1:50,000) is a digital representation of the stream network of British Columbia along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

A variety of remotely sensed imagery could be used to conduct change detection analysis (such as Landsat TM, SPOT, IKONOS, IRS). The type of imagery selected will determine the accuracy of the analysis

Forest type maps focus primarily on commercial timber species, are of uncertain reliability in some locations and are lacking in some locations (e.g., older protected areas). Forest inventories have been incrementally upgraded over time, thus losing the capability of providing temporal trends in vegetation. (Brown and Dick2001).

Forest type maps (focusing on commercial timber species) have been maintained by the Ministry of Forests for many years. (Brown and Dick 2001).

Terrestrial and predictive ecosystem mapping are available from the B.C. Ministry of Sustainable Resource Management and are used to make interpretations on habitat capability and present condition for a broad array of species. These datasets are much more ecologically relevant, but currently cover only 25% of the province and are useful as a baseline only.

Complete provincial coverage and some time-series information on the general spatial distribution / patterns of broad forest age classes within ecoregions are available through the Baseline Thematic Mapping (BTM) initiative. This monitoring source is potentially very useful for provincial or regional level assessments of vegetative condition. There are, however, limitations on the level of detail that can be appropriately interpreted from this monitoring information, given that it is derived primarily from satellite imagery. As well, although BTM coverage exists for the entire province (1992–98 data), a second "pass" was only approximately 20% complete at the time, and this was considered to limit the ability to interpret time-series change (Brown and Dick 2001).

A Vegetation Resource Inventory has been developed by the B.C. Ministry of Forests and Range. This inventory describes forestry resource location and types; however, full coverage of B.C. is not yet available.

The National Forest Inventory is available through the B.C. Ministry of Forests and Range. This inventory was developed to provide the province the ability to report nationally on the current status of the forest resource in B.C. and to monitor changes in the forest. This inventory closely parallel's the Vegetation Resource Inventory attribute information and is incorporated into the National database.

Floodplain maps are available through the B.C. Ministry of Sustainable Resource Management's Floodplain Mapping Program. This program was a joint federal / provincial initiative to provide information to help minimize flood damage. The program identified and mapped areas that were highly susceptible to flooding.

Data Analysis Required: Change detection analysis will be required using satellite imagery; vegetation mapping; Land Registry records; etc. This would require detailed harmonization of current and historical information, which would be easier for smaller sized geographic areas.

Benchmarks: Development of thresholds / criteria is likely to be watershed and/or CU specific, leading from measures necessary to maintain required habitat characteristics in and along the watercourse itself. Gustavson and Brown (2002) [Precision Identification Biological Consultants (1998)] suggest a threshold of an effective impermeable area (EIA) covering approximately 10%, or greater, of the stream's watershed represents a high risk.

Cost: Cost will vary depending upon the CU and data availability. A pilot project would help to clarify costs.

Pro:

Con:

Recommendation:

Indicator Category: **Land Use Conversion**

Candidate Indicator: **Miles of road by type and road crossings within one kilometer of salmonid streams, floodplains, and estuarine shorelines (includes railways)**

Source for Indicator: Green Mountain Institute (1998); Ward (1999); Gustavson and Brown (2002); Knight Piésold (2002)—referred to as road density

Indicator Type: Pressure

Indicator Rationale: Roads and road crossings can have important and cumulative effects on water quality, substrate, and fish passage.

Indicator Definition / Overview: Miles of road by type and road crossings within one kilometer of salmonid streams, floodplains, and estuarine shorelines (includes railways).

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Miles of road by type and road crossings could be monitored over time with comparisons on an annual basis.

Data Availability / Quality:

The B.C. Terrain Resource Information Mapping (TRIM) data (1:20,000) transportation layer contains information on railways, trails, airfields, pipelines, bridges and transmission lines. TRIM also includes data on roads, including primary and secondary roads, other non-forest and forest service roads, and other forest roads. While many other road datasets exist, TRIM data are updated regularly.

The Digital Road Atlas is another roads layer that contains a complete and accurate road network for all roads in B.C. The data have been compiled from multiple existing sources, such as TRIM, Ministry of Forest resource roads and Ministry of Transportation highway information, and is updated frequently. Access to the data is by subscription.

The British Columbia Watershed Atlas (1:50,000) is a digital representation of the stream network of British Columbia along with watershed boundaries of 3rd order and higher watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

The B.C. Fish Inventory Summary System (FISS) (1:50,000) provides spatially represented summary level fish and fish habitat data for waterbodies throughout B.C. and the Yukon. FISS is a jointly funded project by B.C. Fisheries and Fisheries and Oceans Canada. FISS is made up of data and map components. Fish and fish habitat themes included are: fish distribution; enhancement and management activities and objectives; gradient and macro-reaches; land use; water use; water quality activities; obstructions; resource use; flow; fisheries potential and constraints; escapement; value and sensitivity; life history and timing; and harvest and use.

A variety of remotely sensed imagery (such as Landsat TM, SPOT, IKONOS, IRS) could be used to conduct change detection analysis. The type of imagery selected will determine the accuracy of the analysis.

Floodplain maps are available through the B.C. Ministry of Sustainable Resource Management's Floodplain Mapping Program. This program was a joint initiative by the federal and B.C. governments to provide information to help minimize flood damage in British Columbia. The program identified and mapped areas that were highly susceptible to flooding.
Data Analysis Required: Length of road by type (primary and secondary; other non-forest, forest service; and other forest) can be calculated using TRIM data (Gustavson and Brown 2002). Road crossings within one kilometer of salmonid streams, floodplains, and estuarine shorelines (includes railways) may be able to be calculated using TRIM data, the Watershed Atlas and FISS data. Updated data could be compared with past records on an annual basis.
Benchmarks: Establishing thresholds for miles of road by type and road crossings within one kilometer of salmonid streams, floodplains, and estuarine shorelines (includes railways) could be difficult. Location specific considerations would include: slope; soil type; type of fish habitat in watercourse; etc.
Cost: Data gathering and comparisons using TRIM would likely be cost effective.
Pro: The indicator is relevant and robust, data are available, and it can be applied cost effectively.
Con: Identifying thresholds and confirming linkages with the productive capacity of salmon habitat could be challenging.
Recommendation: Implement indicator on a broad scale. Implement on pilot CUs, with monitoring, to build information base related to linkage and thresholds.

Indicator Category: **Land Use Conversion**

Candidate Indicator: **% impervious surface in a watershed**

Source for Indicator:
Green Mountain Institute (1998)
Ward (1999)
From Gustavson and Brown (2002):

- Wild, Threatened and Endangered Streams of the Lower Fraser Valley (Precision Identification Biological Consultants 1998)
- Eclipse Environmental Consulting Ltd. (1998)

Indicator Type: Pressure

Indicator Rationale: Gustavson and Brown (2002) indicate that impervious surfaces affect peak flow rates and can cause a reduction in riparian habitat availability.

Indicator Definition / Overview: Percent of impervious surface (roads, rooftops, and parking lots) in a watershed (Ward 1999).

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:
The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

A variety of remotely sensed imagery could be used to conduct change detection analysis (such as Landsat TM, SPOT, IKONOS, IRS). The type of imagery selected will determine the accuracy of the analysis.

Complete and detailed DFO data are available as of 1999 for non-forest environments in the Lower Mainland. Data for forested environments are; however, generally unavailable, although BTM can calculate "urban" land use. Road surface area is also unavailable (only road length information is available). BTM information on urban land use is sufficiently accurate for strategic applications; however, this data source alone would not permit measurement of this indicator (Gustavson and Brown 2002).

Ward (1999) found that for the Snohomish River Basin there was a limited amount of detailed land use information available to calculate the percent total impervious area (% TIA) for this indicator. As a result, a less complicated measure of the % TIA was developed using road density (kilometers of road/square kilometer of basin) as a surrogate.

Data Analysis Required:

In order to determine % impervious surface, data for the different types of impervious surfaces would have to be integrated, classified and analysed. While satellite imagery may be one primary tool, it is likely that information from other sources would also be required. A considerable amount of effort may be needed to identify the information sources for any given CU, obtain and normalize the information and compile it into a calculated value for the indicator.

Analysis and interpretation would require classification of different types of impervious surface in a manner that reflects different levels of risk to fish and fish habitat (e.g., ranking "imperviousness" with respect to impact; Eclipse Environmental Consulting Ltd. 1998) (Gustavson and Brown 2002).

Benchmarks: Gustavson and Brown (2002) [Precision Identification Biological Consultants (1998)] suggest a threshold of an effective impermeable area (EIA) covering approximately 10%, or greater, of the stream's watershed represents a high risk.

Cost: A considerable amount of effort may be needed to identify the information sources for any given CU, obtain and normalize the information and compile it into a calculated value for the indicator.

Pro: This is a clearly defined indicator that is easily understood.
Eclipse Environmental Consulting Ltd. (1998) ranked this indicator "high".

Con: Compiling a value for this indicator could be quite labour intensive and costly. The specific links to salmon production in a given CU may have to be defined.

Recommendation:

Indicator Category: **Water Quantity**

Candidate Indicator: **Instream flow**

Source for Indicator:
Eclipse Environmental (1998)
Knight Piésold (2002)
From Gustavson and Brown (2002):

- The Pacific Northwest Salmon Habitat Indicators Work Group (Green Mountain Institute 1998);
- [For Forests:
    - Canadian Council of Forest Ministers (1995);
    - Kamloops LRMP
    - Innovative Forest Practices Agreement (IFPA)
    - Monitoring (Kamloops Inter-agency Management Committee 1999);
    - Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000);
    - Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996; Forest Stewardship Council 2001).]

Indicator Type: State - Impact

Rationale: Instream flow is fundamental to aquatic ecosystem integrity and fish production.

Indicator Definition / Overview:

Percent of stream kilometers with instream flow meeting regulatory requirements and seasonal flow requirements for salmonids, and/or sufficient to allow salmon access (Ward 1999).

Assessed waterbodies with adequate flow to meet salmonid requirements, as measured by % of waterbodies, number of waterbodies, % of particular stream classes, meeting flow requirements (Eclipse Environmental 1998).

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☐	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

- Includes direct measurements, derived information and assessment—including low, peak and Mean Annual Discharge (MAD) flow measurements—and information on geomorphology and hydrology.
- Presented separately for each species and salmonid flow regime requirement, depending on salmonid species life histories.
- Flow level measurement alone does not provide sufficient information. Refinement of the key elements—or limiting factors—of an "adequate" flow regime for each salmonid species is needed.
- Peak flow vs. low flow is fundamental. Three factors are low, variable and seasonal flow regimes. Low flows are difficult to predict and regionalized. It may be possible to prioritize low flow problem areas.

(Eclipse Environmental 1998)

Data Availability / Quality:

Water Survey of Canada monitoring data consist of site data that comprise SEAM (System for Environmental Assessment and Management) and EMS (Environmental Monitoring System).

Provincial water monitoring is conducted in domestic use watersheds. Requires direct continuous measurement of discharge at select critical or representative points, focusing on peak flows, low flows and mean annual discharge (Gustavson and Brown 2002).

Currently there are over 500 Water Survey Hydrometric Stations in B.C. that provide data on water flow, water level, sediment concentration or sediment load, and water temperature (Brown and Dick 2001). Past data since 1970 are available for 2400 stations in B.C. from Environment Canada; however, sampling station location and frequency is likely poorly suited to status and trend monitoring (Knight Piésold 2002).

Data gaps may be partially rectified by utilizing data from Forest Renewal B.C. surveys and other site-specific programs; however sampling methods, effort and the type of data report will vary among studies; and streams sampled are unlikely to be representative of all stream or reference streams (Knight Piésold 2002).

Where a dataset is available, it is generally thought to be of high quality. However, the provincial stream flow monitoring network is limited (and has shrunk over the years), thus limiting the ability to tie stream flow effects to specific land uses (Gustavson and Brown 2002).

Knight Piésold indicate that time series streamflow data are available from Water Survey of Canada stations for some locations but are limited spatially and unlikely to be available for all existing or proposed fish status and trend monitoring locations. Additional stream flow information would be available from B.C. Hydro and private sector monitoring programs.

Data Analysis Required: Analysis on Instream Flow requirement on a CU basis would be required, and monitoring over time.

Benchmarks:

Flow requirements differ by fish species; the interpretation depends on the species in question and local geomorphological and hydrological conditions (Eclipse Environmental Consulting Ltd. 1998, Gustavson and Brown 2002).

Further work could potentially identify flow requirements for select fish species by region, given the measurement of other critical local habitat attributes, but this would require extensive field and modelling work (Gustavson and Brown 2002).

Focusing attention on potential "low flow problem areas", for which stream flows were below defined thresholds for fish survival, could reduce data requirements for analysis and interpretation (as alternative to looking for changes in stream flows over time) (Gustavson and Brown 2002).

Cost:

Pro: Eclipse Environmental (1998) ranked this indicator "High". Knight Piésold (2002) indicated that instream flow was considered one of the most useful indicators for status and trend monitoring.

Con:

Recommendation:

Indicator Category: **Water Quantity**

Candidate Indicator: **Flow hydrology**

Source for Indicator:
Eclipse Environmental (1998)
Green Mountain Institute (1998)
Ward (1999)
Knight Piésold (2002)

Indicator Type: Pressure-State - Impact-Response

Rationale: Flow Hydrology is an important driver for aquatic systems.

Indicator Definition / Overview: Percent of waterbodies with minimal, moderate, extreme changes in hydrology from historical patterns (captures low and high flow extremes—deviation) (Ward 1999).

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☐	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

Water Survey of Canada monitoring data consist of site data that comprise SEAM (System for Environmental Assessment and Management) and EMS (Environmental Monitoring System). Currently there are over 500 Water Survey Hydrometric Stations in B.C. that provide data on water flow, water level, sediment concentration or sediment load, and water temperature (Brown and Dick 2001). Past data since 1970 are available for 2400 stations in B.C. from Environment Canada; however, sampling station location and frequency is likely poorly suited to status and trend monitoring (Knight Piésold 2002). Knight Piésold indicate that time series streamflow data are available from Water Survey of Canada stations for some locations but are limited spatially and unlikely to be available for all existing or proposed fish status and trend monitoring locations. Additional stream flow information would be available from B.C. Hydro and private sector monitoring programs.

Provincial water monitoring is also conducted in domestic use watersheds. Requires direct continuous measurement of discharge at select critical or representative points, focusing on peak flows, low flows and mean annual discharge (Gustavson and Brown 2002).

Data gaps may be partially rectified by utilizing data from Forest Renewal B.C. surveys and other site-specific programs; however sampling methods, effort and the type of data report will vary among studies. Streams sampled are unlikely to be representative of all streams or reference streams (Knight Piésold 2002).

Where a dataset is available, it is generally thought to be of high quality. However, the provincial stream flow monitoring network is limited, thus limiting the ability to tie stream flow effects to specific land uses (Gustavson and Brown 2002).

Knight Piésold indicate that time series streamflow data are available from Water Survey of Canada stations for some locations but are limited spatially and unlikely to be available for all existing or proposed fish status and trend monitoring locations. Additional stream flow information would be available from B.C. Hydro and private sector monitoring programs.
Data Analysis Required:
Benchmarks:
Cost:
Pro:
Con:
Recommendation:

Indicator Category: **Physical Habitat and Hydrology**

Candidate Indicator: **Channel width / depth**

Source for Indicator: Green Mountain Institute (1998); Ward (1999); Knight Piésold (2002)
From Gustavson and Brown (2002):

- [For Forests: Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000).]

Indicator Type: State - Impact

Rationale: Channel width and depth can affect water quality (e.g., temperature), sediment transport, and cover, making this an important fish habitat characteristic.

Indicator Definition / Overview: Stream Depth: Variance of thalweg depths (flow path of the deepest water in a stream) (Ward 1999). Thalweg depth is the deepest portion of the stream at a given cross section. A stream profile (i.e., along the stream axis) provides a number of sample points from which to derive a variance measure (Gustavson and Brown 2002).

Application Level:		Comments:
Region / Province	☐	
Watershed	☐	
Sub-watershed	☐	
Lake	☐	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

Gustavson and Brown (2002) indicate that data for measuring this indicator are not available in corporate databases. Data do exist in various studies for individual watersheds and in watershed assessment reports.

Where data exist, the data can be expected to be reliable provided collection was completed using accepted inventory protocols and standards.

Channel width could be extracted from high resolution remotely sensed imagery (IKONOS).

Data Analysis Required: Channel width could be extracted from high resolution remotely sensed imagery (IKONOS).

Benchmarks: A significant decrease in thalweg depth variance in the sample streams from previous year(s) represents a risk to fish sustainability (Gustavson and Brown 2002).

The greater the variance in thalweg depth, measured from a representative sample of fish bearing streams by watershed, the greater the habitat complexity (Gustavson and Brown 2002).

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Physical Habitat**

Candidate Indicator: **Sediment—change in sediment loading**

Source for Indicator: Eclipse Environmental (1998); Green Mountain Institute (1998); Ward (1999)
From Gustavson and Brown (2002):

- [For Forests: Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000).]

Indicator Type: State - Impact

Rationale: Increases in sediment loading is known to decrease production in aquatic habitat. Effects include impairment of water quality and increased embeddedness.

Indicator Definition / Overview: Change in sediment loading rates.

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality: Federal Water Survey Hydrometric Stations: Currently there are approximately 500 stations in B.C. including data on water flow, water level, sediment concentration or sediment load and water temperature (Knight Piésold 2002, Brown and Dick 2001). Past data since 1970 are available for 2400 stations from Environmental Canada; however, sampling location and frequency are likely poorly suited to status and trend monitoring (Knight Piésold 2002).

The Ministry of Energy, Mines, and Petroleum Resources hosts a digital terrain mapping library that provides terrain and slope stability related data across B.C. The data are available at a variety of scales from 1:1,000 to 1:1,000,000.

The Ministry of Sustainable Resource Management has developed a 25 m Digital Elevation Model (DEM) developed from 1:20,000 TRIM data.

Data Analysis Required: Analysis of time series TSS data and related substrate characteristics.

Benchmarks: For protection of aquatic life, British Columbia Water Quality Guidelines define maximum induced suspended sediments as 25 mg/L in 24 hours and mean of 5 mg/L in 30 days when background is less than or equal to 25; 25 mg/L when background is between 25 and 250; and 10% when background is greater than or equal to 250 (Gustavson and Brown 2002) [Ministry of Water, Land and Air Protection 1998].

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Physical Habitat and Hydrology**

Candidate Indicator: **Substrate**

Source for Indicator:
Green Mountain Institute (1998)—as Sediment
Ward (1999)—as Sediment
Knight Piésold (2002)

Indicator Type: State and Impact

Rationale: Good quality gravel substrate is essential for spawning and growth of aquatic macroinvertebrates.

Indicator Definition / Overview:

Application Level:		Comments:
Region / Province	☐	
Watershed	☐	
Sub-watershed	☐	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Substrate can be used as an indicator of spawning gravel suitability, and therefore as a surrogate to spawning success.

Data Availability / Quality: Data on Substrate are available for some parts of B.C. through the Community Mapping Network Atlases (e.g., Sensitive Habitat Inventory and Mapping (SHIM) Atlas).

Data Analysis Required:

Benchmarks: For protection of aquatic life, B.C. Water Quality Guidelines define streambed substrate composition as fines not to exceed 10% as less than 2mm, 19% as less than 3mm, and 25% as less than 6.35mm at salmonid spawning sites. The geometric mean diameter must be not less than 12mm, and the Fredle number not less than 5mm (Gustavson and Brown 2002) [Ministry of Water, Land and Air Protection 1998].

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Physical Habitat**

Candidate Indicator: **Spawning area**

Source for Indicator: Green Mountain Institute (1998); Ward (1999); From Gustavson and Brown (2002):

- [For Forests: Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996; Forest Stewardship Council 2001).]

Indicator Type: State and Impact

Rationale: The area available for spawning is an important determinant for the number of juveniles produced from a system.

Indicator Definition / Overview: % change in spawning areas (Ward 1999).

Application Level:		Comments:
Region / Province	☐	
Watershed	☐	
Sub-watershed	☐	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality: The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas can be used to delineate watersheds, and will be helpful in analysis.

A variety of remotely sensed imagery could be used to conduct change detection analysis (such as Landsat TM, SPOT, IKONOS, IRS). The type of imagery selected will determine the accuracy of the analysis.

B.C. Fish Inventory Summary System (FISS) (1:50,000) provides spatially represented summary level fish and fish habitat data for waterbodies throughout B.C. and the Yukon. FISS is a project jointly funded by B.C. Fisheries and DFO. FISS is made up of data and map components. Fish and fish habitat themes included are: fish distribution; enhancement and management activities and objectives; gradient and macro-reaches; land use; water use; water quality activities; obstructions; resource use; flow; fisheries potential and constraints; escapement; value and sensitivity; life history and timing; and harvest and use.

Data on Spawning are available for some parts of B.C. through the Community Mapping Network Atlases (e.g., Sensitive Habitat Inventory and Mapping Atlas).

Data Analysis Required:

Benchmarks:

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Physical Habitat**

Candidate Indicator: **Habitat type associated with water—off channel, wetland**

Source for Indicator: Green Mountain Institute (1998); Ward (1999)

Indicator Type: State and Impact

Rationale: Off-channel and wetland habitat are important for spawning and rearing for some species and life stages.

Indicator Definition / Overview: The amount of habitat, by category (e.g., off-channel, wetland) associated with the water margins of the water course in a watershed and the value of the habitat to the salmonid life-cycle (Ward 1999).

Application Level:		Comments:
Region / Province	☐	
Watershed	☐	
Sub-watershed	☐	
Lake	☐	
River	☑	
Stream	☐	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

B.C. Fish Inventory Summary System (FISS) (1:50,000) provides spatially represented summary level fish and fish habitat data for waterbodies throughout B.C. and the Yukon. FISS is a project jointly funded by B.C. Fisheries and DFO. FISS is made up of data and map components. Fish and fish habitat themes included are: fish distribution; enhancement and management activities and objectives; gradient and macro-reaches; land use; water use; water quality activities; obstructions; resource use; flow; fisheries potential and constraints; escapement; value and sensitivity; life history and timing; and harvest and use.

Terrestrial and predictive ecosystem mapping (TEM and PEM) are available from MELP and are used to make interpretations on habitat capability and present condition for a broad array of species. This dataset is much more ecologically relevant, but currently covers only 25% of the province and is useful as a baseline only.

Complete provincial coverage and some time-series information on the general spatial distribution / patterns of broad forest age classes within ecoregions are available through the BTM initiative. This monitoring source is potentially very useful for provincial or regional level assessments of vegetative condition. There are, however, limitations on the level of detail that is appropriately interpreted from this monitoring information, given that it is derived primarily from satellite imagery. As well, although BTM coverage exists for all of the province (1992–98 data), a second “pass” is only approximately 20% complete, and this limits the ability to interpret time-series change (Brown and Dick 2001).

A variety of remotely sensed imagery could be used to conduct a classification of various habitat types (such as Landsat or IKONOS). The type of imagery selected will determine the accuracy of the analysis.

Data Analysis Required: Change in estuarine area, by type and quality (Pacific Northwest Salmon Habitat Indicators Work Group). Change in area of side channel habitat (Pacific Northwest Salmon Habitat Indicators Work Group). Change in wetland area (Pacific Northwest Salmon Habitat Indicators Work Group). Number of wetlands identified and protected (Forest Certification). Extent to which productive habitats of selected species or species guilds are distributed throughout the range of their habitat (IFPA).
Benchmarks: Analysis and interpretation may require development of thresholds of impact (risk) to these aquatic habitats, although general trends information on the direction of change could be assumed (Gustavson and Brown 2002).
Cost:
Pro:
Con:
Recommendation:

Indicator Category: **Physical Habitat**

Candidate Indicator: **Impediments to accessibility to salmon habitat**

Source for Indicator:
Eclipse Environmental (1998)
Green Mountain Institute (1998)
Ward (1999)
From Gustavson and Brown (2002):

- [For Forests: Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996; Forest Stewardship Council 2001).]

Dent et al. (2005)

Indicator Type: State and Impact

Rationale: Barriers to accessibility can limit or destroy a CU. Barriers can be created deliberately (dams) or inadvertently (improper culverts).

Indicator Definition / Overview:

Number of locations where salmon are impeded, by type (Ward 1999).

Anthropogenic and natural barriers. An impediment is defined as "something which blocks fish" (i.e., if fish can get around a dam then the dam does not impede them). This includes culverts and other site level barriers. (Eclipse Environmental Consulting 1998)

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality: The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

The B.C. Fish Inventory Summary System (FISS) (1:50,000) database includes point data on fish impediments including culverts, waterfalls, gradient changes, dams, and road fill. FISS data on stream obstructions is generally accurate for the locations where data exist, as of the date that the data were captured. Reliability is limited by the ability to maintain updated records for all provincial watersheds (Gustavson and Brown 2002).

Construction and operation of dams and stream diversions require a licence under the B.C. Water Act. There are approximately 2500 authorized dams in B.C., 200 of which exceed 9.0 m in height and are classified as regional. Water License information is administered by the B.C. Ministry of Sustainable Resource Management Water Planning and Allocation Branch. B.C. Hydro also has extensive information concerning the location and the historical impacts of Crown-operated hydroelectric facilities (Knight Piésold 2002).

The proposed indicator may be useful to illustrate historical impacts on fish habitat based on outdated approaches to natural resource management. However, it may not be useful to monitor future trends if policy no longer permits this type of habitat alteration. Much of the required information is easily accessible through existing government and Crown Corporation databases (Knight Piésold 2002). Information concerning historical fish distribution upstream of anthropogenic barriers may be unavailable. There are also several categories of fish barriers and water use that restrict but may not necessarily block fish migration at all flows. Stratifying known or potential fish barrier by type may improve resolution of the analysis. As noted previously, anthropogenic barriers provide an index of historical habitat degradation (Knight Piésold 2002). The B.C. Ministry of Energy, Mines, and Petroleum Resources hosts a Digital Terrain Mapping Library that provides terrain and slope stability related data across the province. The data are available at a variety of scales from 1:1,000 to 1:1,000,000.
Data Analysis Required: Identification of existing impediments through database and records searches and tracking of new impediments that may result from slope instability, improperly installed culverts, etc.
Benchmarks:
Cost:
Pro: Barriers to fish movement were ranked "high" and an indicator at a B.C./DFO workshop in 1998 (Eclipse Environmental Consulting 1998).
Con:
Recommendation:

Indicator Category: **Physical Habitat**

Candidate Indicator: **Large woody debris**

Source for Indicator:

Green Mountain Institute (1998)

Ward (1999)

From Gustavson and Brown (2002):

- [For Forests: Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996; Forest Stewardship Council 2001); Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000).]

Norton-Arnold & Company (2005)

Tripp et al. (2005)

Indicator Type: State and Impact

Rationale: Large woody debris is an important component of aquatic and fish habitat, providing cover and habitat complexity. In some cases, it can also cause impediments to fish access. Both aspect warrant attention.

Indicator Definition / Overview:

Counts of debris pieces with lengths equal or greater than channel widths, noting presence/absence of root wads, per historically anadromous salmonid stream kilometer (Ward 1999).

Distribution and characterisation of large woody debris per historically anadromous salmonid stream mile (Pacific Northwest Salmon Habitat Indicators Work Group).

Coarse woody debris in streams that is added or removed (Forest Certification).

Presence and density of course woody debris (Model Forests).

Application Level:		Comments:
Region / Province	☐	
Watershed	☐	
Sub-watershed	☐	
Lake	☐	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

Large Woody Debris is a standard site-level field measurement for forested stream fish habitat inventory and monitoring programs in B.C. and other jurisdictions. When operationally defined, Large Woody Debris volume and position can be measured with some precision (Knight Piésold 2002 [Ralph et al. 1994]).

Large Woody Debris frequency is subject to high natural variation that is reduced by stratifying data by landscape and channel type, channel gradient, and basin area. Several numeric criteria have been applied to Large Woody Debris in streams. For example, the PACFISH strategy identified properly functioning coastal streams as having 80 pieces of Large Woody Debris per mile, 24' in diameter and 50' in length (Knight Piésold 2002 [FS and BLM, 1995]).

Data for measuring this indicator are not available in corporate databases. Data do exist in various studies for individual watersheds and in watershed assessment reports (Gustavson and Brown 2002).

Estimates of volumes of large woody debris can be prone to large measurement errors (i.e., not replicable due to differences between individuals doing the measurements and difficulties associated with estimating complex log assemblages or log jams) (Gustavson and Brown 2002) [Hogan 2001].

Data Analysis Required:

Benchmarks:

Thresholds for what defines desired levels of large woody debris in streams would be needed. More large woody debris is not always better—there are limits (Gustavson and Brown 2002).

Measuring the orientation of large woody debris may be another possible measure (i.e., as an indication of stream energy due to water flow regime which, in turn, can be affected by land use activities) (Gustavson and Brown 2002).

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Water Quality**

Candidate Indicator: **Temperature**

Source for Indicator:
Eclipse Environmental (1998)
Green Mountain Institute (1998)
Ward (1999)
Knight Piésold (2002)
From Gustavson and Brown (2002):

- [For Forests:
    - Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000);
    - Innovative Forest Practices Agreement (IFPA).]

OWEB (2003)
Dent et al. (2005)

Indicator Type: State and Impact

Rationale: Temperature is a prime determinant with respect to the suitability and production of fish habitat.

Indicator Definition / Overview:
Percent of assessed waterbodies where the daily maximum falls into the following categories:
<10 degrees C—no impairment;
10–15 degrees C—potential impairment to sensitive species;
15–20 degrees C—moderate impairment;
>20 degrees C—severe impairment (Ward 1999).

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Temperature can be easily monitored and broadly applied as a basic measure of fish habitat suitability.

Data Availability / Quality:

Gustavson and Brown (2002) indicate that corporate databases for stream temperatures are available for limited number of streams in HYDAT and WIDMS. Coverage of watersheds of interest will likely require expanding sampling efforts, establishing a consistent representative set of streams.

The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

The B.C. Fish Inventory Summary System (FISS) (1:50,000) provides spatially represented summary level fish and fish habitat data for waterbodies throughout B.C. and the Yukon. FISS is a project jointly funded by B.C. Fisheries and DFO. FISS is made up of data and map components. Fish and fish habitat themes included are: fish distribution enhancement and management activities and objectives; gradient and macro-reaches; land use; water use; water quality activities; obstructions; resource use; flow; fisheries potential and constraints; escapement; value and sensitivity; life history and timing; and harvest and use.

The Aquatic Ecozone Classification Database (AECD) contains 300,000 records for water quality variables that include temperature for lakes and streams in B.C. (primarily southern regions). They are divided into aquatic ecozones (45 Ecoregions in 8 Ecoprovinces) based on homogeneity of water quality within and among 245 watershed groups. The database includes digital and non-digital sources such as the provincial Environmental Monitoring System (EMS) data-base (formerly the SEAM databases), the Environmental Trends Database [MWLAP, 2000], and Federal Water Survey of Canada (WSC) Hydrometric Stations (Knight Piésold 2002).

Note: A recent reference to this database was not found. Confirmation of status is required.

The B.C. Water Inventory Data Management System (WIDMS) and includes water quality data (temperature, pH, conductivity, turbidity, and depth) for surface waters in approximately 60 community watersheds. However, this data set is spatially and temporally limited. Similar to other programs in B.C., the frequency of existing water quality data is insufficient to provide real time series information (Knight Piésold 2002).

Federal Water Survey Hydrometric Stations: Currently there are approximately 500 stations in B.C. that provide data on water flow, water level, sediment concentration or sediment load and water temperature (Knight Piésold 2002) [Brown and Dick, 2001]. Past data since 1970 are available for 2400 stations from Environmental Canada; however, sampling location and frequency are likely poorly suited to status and trend monitoring (Knight Piésold 2002).

Data Analysis Required:

Analysis will require overlaying fish presence data with stream temperature data to determine when thresholds are exceeded (Gustavson and Brown 2002).

Ward (1999) found that for the Snohomish River Basin, Washington, the process to develop this indicator was quite labor intensive due to the fact that much of the data were obtained from printed reports which were visually scanned to determine daily peak temperatures.

The greater the daily maximum temperature above that optimum for fish species (and for life history stages of those species), measured from a representative sample of fish bearing streams by watershed, the greater the risk to fish sustainability (Gustavson and Brown 2002).

Benchmarks:

- 15–20 degrees C—moderate impairment;
- >20 degrees C—severe impairment (Ward 1999).

Cost: Temperature can be monitored continuously and inexpensively using temperature recorders.

Pro: Knight Piésold (2002) found that, among water quality indicators, temperature ranked as the most useful overall for streams, having a high relevance, low cost and good data availability.

Con:

Recommendation:

Indicator Category: **Biological Water Quality**

Candidate Indicator: **Macroinvertebrates**

Source for Indicator:
Green Mountain Institute (1998) as part of Biological Water Quality Index
Ward (1999) as part of Biological Water Quality Index
Knight Piésold (2002)
From Gustavson and Brown (2002):

- Environmental Trends Reporting (Ministry of Environment, Lands and Parks 2000)

Dent et al. (2005) as part of Coldwater Index of Biotic Integrity
Tripp et al. (2005)

Indicator Type: State - Impact

Rationale: Benthic macroinvertebrate communities integrate other indicators of aquatic ecosystem health and are sensitive indicators of degradation.

Indicator Definition / Overview: Species composition, biomass, percent EPT, tolerant versus intolerant species, functional guilds (Knight Piésold 2002).

Application Level:		Comments:
Region / Province	☐	Application to lakes would be on a site-specific basis.
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Knight Piésold (2002) indicated that benthic macroinvertebrates are more useful for streams than for lakes.

Data Availability / Quality: Knight Piésold (2002) indicate that accessible benthic invertebrate data in B.C. are limited. Knight Piésold (2002) states that most biological monitoring data are available only on a site specific basis (EEM and other permit compliance monitoring programs) and are poorly suited for use in broad scale status and trend monitoring or for developing Biological Index of Biological Integrity standards.

Data Analysis Required: For biological water quality, any analysis will require sampling of watersheds using a consistent representative set of streams (Gustavson and Brown 2002).

Benchmarks: Recommend use of a proportional abundance-based diversity index (e.g., Shannon index as a measure of complexity) (Gustavson and Brown 2002). The greater the benthic macroinvertebrate diversity, measured from a representative sample of fish bearing streams by watershed, the greater the "options" for ecosystem development and, likely, the greater the stream productivity (Gustavson and Brown 2002). A significant decrease in benthic macroinvertebrate diversity in the sample streams from previous year(s), represents a risk to fish sustainability (Gustavson and Brown 2002).
Cost: Knight Piésold (2002) indicates that costs for biological water quality monitoring are similar to other aquatic field surveys, and that laboratory costs are greater than for fish communities. With the exception of multivariate methods, data analysis and summary are relatively simple.
Pro:
Con:
Recommendation:

Indicator Category: **Biological Water Quality**		
Candidate Indicator: **Zooplankton, Phytoplankton and Chlorophyll *a***		
Source for Indicator: Knight Piésold (2002) From Gustavson and Brown (2002): ▪ Environmental Trends Reporting (Ministry of Environment, Lands and Parks 2000)		
Indicator Type: State - Impact		
Rationale: Provides information relevant to production (particularly relevant to lake environments for sockeye rearing) and on water quality (eutrophication).		
Indicator Definition / Overview: Species composition, biomass, indicator species (Knight Piésold 2002).		
Application Level: Region / Province Watershed Sub-watershed Lake River Stream Estuary	 ☐ ☑ ☑ ☑ ☐ ☐ ☐	Comments:
Application Species: Chinook Coho Sockeye Pink Chum	 ☑ ☑ ☑ ☐ ☐	Comments:
Indicator Application:		
Data Availability / Quality: Little periphyton and plankton information is available on a broad spatial or temporal scale. There are relatively extensive chlorophyll *a* data available from B.C. environment trends reporting (Knight Piésold 2002). Among the water quality variables, chlorophyll *a* is the only one that is widely available (Knight Piésold 2002). Data are available for specific sockeye rearing lakes through DFO programs.		
Data Analysis Required:		
Benchmarks:		
Cost:		
Pro:		
Con:		
Recommendation:		

Indicator Category: **Chemical Water Quality**

Candidate Indicator: **Dissolved oxygen, pH, TDS, alkalinity, TSS, turbidity**

Source for Indicator:
Eclipse Environmental Consulting (1998)
Green Mountain Institute (1998)
Ward (1999)
Knight Piésold (2002)
Gustavson and Brown (2002):

- Environmental Trends Reporting (Ministry of Environment, Lands and Parks 2000);
- [For Forests:
    - Canadian Council of Forest Ministers (1995);
    - Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000).]

Dent et al. (2005)

Indicator Type: State - Impact

Rationale: Good water quality is essential for salmon production.

Indicator Definition / Overview:
Percent of waters rated excellent, good, fair, poor (parameters would include dissolved oxygen, pH, TDS, Alkalinity, TSS, Turbidity)

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Dissolved Oxygen, pH, TDS, Alkalinity, TSS, Turbidity can be applied to draw conclusions on: whether conditions are improving; staying the same; or deteriorating over time. They can also be used to identify situations where conditions are stressful for fish, which might limit growth, survival, etc. These parameters can be to identify situations where conditions are marginal or unacceptable for salmon life cycle stages.

Data Availability / Quality:

Gustavson and Brown (2002) indicated that chemical water quality data were generally not available in corporate (presumed to mean Province of B.C.) databases. It was noted that where data are available, they are accepted as generally high quality, although the rationale for this is not clear.

Knight Piésold (2002) indicate that existing data for chemical water quality indicators are biased toward southern regions of B.C., and regions that are more accessible and potentially subject to anthropogenic impacts.

Data Analysis Required: Analysis of Dissolved Oxygen, pH, TDS, Alkalinity, TSS, Turbidity requires consideration of metadata such as: time of year; natural background; flow conditions; sample collection, analysis and QA/QC methodologies; etc.

Benchmarks:

Gustavson and Brown (2002) indicate that water quality data require interpretation to derive conclusions on implications for fish (e.g., into ratings such as "excellent", "good", "fair", "borderline", "poor").

Thresholds can be derived from existing thresholds (e.g., Provincial Standards, CCME Water Quality Criteria) or derived on a site/area/CU specific basis for Dissolved Oxygen, pH, TDS, Alkalinity, TSS, Turbidity.

Cost: Sampling frequency is a major cost constraint for chemical water quality sampling.
TSS is more costly because it requires lab analysis.

Pro:

Con:

Recommendation: Knight Piésold recommended turbidity over TSS due to reduced costs because lab analysis is not required.

Indicator Category: **Chemical Water Quality**

Candidate Indicator: **Nutrients (Nitrate, Nitrite, Ammonia, Total Phosphorous) $\mathbf{BOD_5}$**

Source for Indicator:
Knight Piésold (2002)
Green Mountain Institute (1998)
Gustavson and Brown (2002):

- Environmental Trends Reporting (Ministry of Environment, Lands and Parks 2000);
- [For Forests:
    - Canadian Council of Forest Ministers (1995);
    - Model Forests (McGregor Model Forest Association 1998; Beasley and Wright 2000).]

Indicator Type: State - Impact

Rationale: Provide information relevant to primary production (particularly relevant to lake environments for sockeye rearing) and on water quality (eutrophication).

Indicator Definition / Overview: Percent of waters rated excellent, good, fair, poor (parameters would include Nitrate, Nitrite, Ammonia, Total Phosphorous).

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☐	

Application Species:		Comments:
Chinook	☐	
Coho	☐	
Sockeye	☑	
Pink	☐	
Chum	☐	

Indicator Application: Knight Piésold (2002) indicated that nutrients are more useful as an indicator for lakes than for streams.

Data Availability / Quality: Knight Piésold (2002) indicate that existing data for chemical water quality indicators is biased toward southern regions of B.C., and regions that are more accessible and potentially subject to anthropogenic impacts.

Data Analysis Required:

Benchmarks:

Cost:

Pro:

Con:

Recommendation:

Indicator Category: **Aquatic and Riparian Ecosystems**

Candidate Indicator: **Area, distribution and types of riparian and wetland vegetation**

Source for Indicator:
Eclipse Environmental (1998)
Green Mountain Institute (1998)—as riparian forest under "Habitat Type Associated with Water"
Ward (1999)—as riparian forest under "Habitat Type Associated with Water"
From Gustavson and Brown (2002):

- [For Forests:
    - Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996;
    - Forest Stewardship Council 2001);
    - Innovative Forest Practices Agreement (IFPA).]

Dent et al. (2005)

Indicator Type: State - Impact

Rationale: Riparian and wetland vegetation contribute to water quality (temperature, nutrients), food supply (invertebrates) and habitat cover.

Indicator Definition / Overview:

Application Level:		Comments:
Region / Province	☐	
Watershed	☑	
Sub-watershed	☑	
Lake	☐	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: This indicator can be quite location specific in terms of data collection and interpretation. Use of existing data collection programs (e.g., those related to forestry) would be essential; however, coverage extending over a CU may be difficult to achieve.

Data Availability / Quality:

The British Columbia Watershed Atlas (1:50,000) is a digital representation of the stream network of British Columbia along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

B.C. TRIM data (1:20,000)

Terrestrial and predictive ecosystem mapping (TEM and PEM) are available from the B.C. Ministry of Sustainable Resource Management and are used to make interpretations on habitat capability and present condition for a broad array of habitat types.

Complete provincial coverage and some time-series information on the general spatial distribution / patterns of broad forest age classes within ecoregions are available through the BTM initiative and the B.C. Watersheds Atlas. This monitoring source is potentially very useful for provincial or regional level assessments of vegetative condition. There are, however, limitations on the level of detail that is appropriately interpreted from this monitoring information, given that it is derived primarily from satellite imagery. As well, although BTM coverage exists for all of B.C. (1992–98 data), it was reported that a second "pass" was only approximately 20% complete, and that this would limit the ability to interpret time-series change (Brown and Dick 2001). Data of logged riparian area is accessible from this dataset, as well as air photography and the B.C. Ministry of Forests Forest Cover Inventory (1:20,000) (Forest Cover Inventory may be up to five years out of date).

A variety of remotely sensed imagery could be used to conduct analysis (such as Landsat TM, SPOT, IKONOS, IRS). The type of imagery selected will determine the accuracy of the analysis. Dent et al. (2005), however, indicated that remote data are of limited value.

Results-based Forest Practices Code implementation may provide an additional data source that enables monitoring of a response indicator for riparian habitat (i.e., number of infractions of riparian management performance standards).

The B.C. Ministry of Energy, Mines, and Petroleum Resources hosts a digital terrain mapping library that provides terrain and slope stability related data across the province. The data are available at a variety of scales from 1:1,000 to 1:1,000,000.

Data Analysis Required:

Image classification using remotely sensed imagery may be used to determine area, distribution and types of riparian and wetland vegetation; however, the level of detail may not be sufficient for use as an indicator (Dent et al. 2005).

Data analysis would likely involve integrating data from multiple sources in electronic and hardcopy formats. The data could be historic or the result of recent collection efforts.

Change detection analysis will be required using information from available mapping, site specific studies, GIS, existing leases, records from land use / regulatory approvals, fish habitat management inventory and planning exercises, satellite imagery, etc.

Benchmarks:

Cost: Information gathering and integration from various sources could be quite expensive.

Pro: Tracking and managing change in area, distribution, types of riparian and wetland vegetation is essential for maintaining wild salmon CUs.

Con:

Recommendation:

Indicator Category: **Estuarine Ecosystems**

Candidate Indicator: **Change in area, distribution, types and change in area of tidal and submerged wetlands**

Source for Indicator: Dent et al. (2005)

Indicator Type: State - Impact

Rationale: Tidal and submerged wetlands in estuaries are essential salmon rearing areas.

Indicator Definition / Overview: Quantification of the area, distribution and types of tidal and submerged wetlands and comparison over time.

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

Province of British Columbia TRIM data (1:20,000)

A variety of remotely sensed imagery could be used to conduct analysis (such as Landsat TM, Radarsat, IKONOS, IRS). The type of imagery selected will determine the accuracy of the analysis.

Coastal Resource Information Management System (CRIMS)—The British Columbia Coastal Resource Information System is an internet based interactive map for viewing coastal and marine data. A wide variety of coast and marine resources are included, such as aquaculture, shoreline classification, selected fisheries information, and offshore oil and gas information. Eelgrass distribution is included in this information management system.

A review of existing eelgrass mapping initiatives was prepared by Dunster & Associates Environmental Consultants Ltd. in March 2003 entitled *Eelgrass Mapping Review—Eelgrass Mapping Initiatives in Coastal British Columbia*. This document along with a variety of data on eelgrass bed locations is available on the Community Mapping Network website within the Eelgrass Bed Mapping Atlas (http://www.shim.bc.ca/atlases/eelgrass/main.htm). Data are presented at a variety of scales within this Atlas.

Terrestrial and predictive ecosystem mapping (TEM and PEM) are available from the B.C. Ministry of Sustainable Resource Management and are used to make interpretations on habitat capability and present condition for a broad array of habitat types.

Dent et al. (2005) indicate that, for Oregon, establishing a baseline would be a challenge.

Data Analysis Required: Change detection analysis will be required using information from available mapping, site specific studies, GIS, existing leases, records from land use / regulatory approvals, fish habitat management inventory and planning exercises, satellite imagery, etc.
Benchmarks:
Cost:
Pro: Tracking and managing change in area, distribution, types and change in area of tidal and submerged wetlands is essential for maintaining wild salmon CUs.
Con:
Recommendation:

Indicator Category: **Estuarine Ecosystems**

Candidate Indicator: **Index of biotic integrity for estuaries**

Source for Indicator: Dent et al. (2005)

Indicator Type: State - Impact

Rationale: Estuaries are essential salmon rearing areas and food supply are important ecosystem components for salmon production.

Indicator Definition / Overview:

Dent et al. (2005) recommend "Index of Biotic Integrity for Estuaries" as an indicator but do not elaborate on the detailed parameters that comprise the index. The definition of an Index of Biotic Integrity (IBI) provided by Dent et al. would; however, require significant adaptation before it could be applied to estuaries: "Observations are compared with those in reference reaches. Separate indices will be established for invertebrates and vertebrates. RIVPACS (a multivariate model) will be used to evaluate invertebrates. A vertebrate multimetric model will be used to evaluate fish and aquatic amphibians. RIVPACS and vertebrate models have been developed (Hughes et al. 1998, 2004) and are available for use. (The current RIVPACS model applies to Western Oregon only.) Periphyton should also be considered as an indicator because it is relatively inexpensive to collect and analyze and is not constrained by a permitting process, as fish sampling is. It is also sensitive to management and can be used to detect various anthropogenic disturbances and stresses."

Anadromous fish indicators focus on a small component of aquatic communities and respond to multiple pressures and conditions that challenge interpretations. Therefore, Dent et al. (2005) recommend using an IBI to broaden understanding of aquatic ecosystems. An IBI provides a more comprehensive index of aquatic organisms, including native fish, and incorporates reference conditions as a measure of the relative "health" of the aquatic environment. An IBI combines measures of multiple biological indicators, such as species richness, relative abundance of specific organisms, and health of the organisms, to rate the condition of the system [(Hughes et al. 1998, Mebane et al. 2003, Hughes et al. 2004)]. The data also can be used to evaluate pressures from introduced species.

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☐	
River	☐	
Stream	☐	
Estuary	☑	

Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application: Dent et al. (2005) indicate that an IBI for Estuaries would need to be developed. This category of indicator has the potential for application in all estuaries, but would require a considerable amount of developmental work before it could be used.

Data Availability / Quality: Once the specific parameters that would comprise the index have been defined then an assessment of Data Availability / Quality can be completed.

Data Analysis Required: It is likely that a considerable amount of data review and analysis would be required in order to use this indicator.

Benchmarks: Thresholds for the indicators would have to be developed.
Cost: Development and application of this indicator has the potential to become quite costly. Definition of the index parameters and subsequent costing would be the logical first steps to assess the feasibility of this index as an indicator.
Pro: An IBI for Estuaries has the potential for integrating information to describe the status of complex estuarine systems into a single index value.
Con: An IBI for Estuaries could be quite challenging and costly to develop. The applicability of an index to each individual species and estuary would require consideration. Data analysis and interpretation could be quite costly and challenging. As with any index, there is a loss of information as multiple variables are factored into one overall value.
Recommendation:

Indicator Category: **Ecosystem Biodiversity**

Candidate Indicator: **At risk species**

Source for Indicator:
Dent et al. (2005)
From Gustavson and Brown (2002):

- Environmental Trends Reporting (Ministry of Environment, Lands and Parks 2000);
- [For Forests:
    - Canadian Council of Forest Ministers (1995);
    - State of Forests Reporting (Ministry of Forests 2000);
    - Forest Certification (American Forest and Paper Association 1995; Canadian Standards Association 1996; Forest Stewardship Council 2001).]

Indicator Type: State - Impact

Rationale: The Wild Pacific Salmon Policy is intended to ensure that wild Pacific salmon CU diversity is maintained.

Indicator Definition / Overview:

Number of CUs considered threatened or endangered.

Habitat availability/quantity/quality for CUs considered threatened or endangered.

Number as a percentage of total number of species (Canadian Council of Forest Ministers; Environmental Trends Reporting).

Number of aquatic species at risk (red or blue listed) (Kamloops LRMP Monitoring).

Habitat availability for selected species at risk (Model Forests).

Presence of red and blue listed species, as well as population and reproductive size (Model Forests).

Trends in classification of red and blue listed species, as well as their habitat condition (Forest Certification).

Application Level:		Comments:
Region / Province	☑	
Watershed	☑	
Sub-watershed	☑	
Lake	☑	
River	☑	
Stream	☑	
Estuary	☑	
Application Species:		Comments:
Chinook	☑	
Coho	☑	
Sockeye	☑	
Pink	☑	
Chum	☑	

Indicator Application:

Data Availability / Quality:

The provincial Conservation Data Centre (CDC) lists rare and endangered species ("red-listed") and vulnerable species ("blue-listed"). Includes plant species, plant communities, vertebrates and invertebrates, ranked on both a provincial (1:50000) and global basis.

The federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC) database lists species designated "at risk" nationally.

Provincial and federal data on species occurrences and the subsequent interpretation into red or blue listed species is generally thought to be reliable; however, it is "anecdotal" to the extent that it is based on limited field studies and reports from various sources, including scientists, naturalists, published and unpublished reports, and museum collections. Absence of data at a location may mean either absence of the species or that the area has not been studied (and may in fact be present) (Gustavson and Brown 2002).

The B.C. Watershed Atlas (1:50,000) is a digital representation of the B.C. stream network along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas should be used to delineate watersheds, and will be helpful in analysis.

The B.C. Fish Inventory Summary System (FISS) (1:50,000) provides spatially represented summary level fish and fish habitat data for waterbodies throughout B.C. and the Yukon. FISS is a project jointly funded by B.C. Fisheries and DFO. FISS is made up of data and map components. Fish and fish habitat themes included are: fish distribution, enhancement and management activities and objectives; gradient and macro-reaches; land use; water use; water quality activities; obstructions; resource use; flow; fisheries potential and constraints; escapement; value and sensitivity; life history and timing; and harvest and use.

Terrestrial and predictive ecosystem mapping (TEM and PEM) are available from MELP and are used to make interpretations on habitat capability and present condition for a broad array of species. These dataset is much more ecologically relevant, but currently covers only 25% of the province and is useful as a baseline only.

The Community Mapping Network supports a Sensitive Habitat Inventory and Mapping Atlas that identifies sensitive aquatic and terrestrial habitats. Data layers present in the Atlas include: Watershed Boundaries (at multiple map scales), Provincial Park Boundaries, Regional District Boundaries, Georgia Basin Boundary, Hydrology (at 1:50,000 and 1:20,000 scale), TRIM features (1:20,000), Local cadastral features (various municipalities), Map grids (multiple scales), FISS and fish presence (1:50,000), SHIM features (1:5000), B.C. Communities, Watershed classifications, Salmon Stock Status, and Orthophotographs.

The Lower Fraser River Stream Inventory Atlas was developed by the Fraser River Action Plan, compiled from information from DFO and B.C. Environment, classifies all watercourses as to whether or not they have known fish populations. The atlas can be consulted by local governments, planners, land developers, resource management agencies, community groups and citizens to help them locate sensitive fish habitat. Two types of maps have been produced: black and white maps at a scale of 1:20,000 and maps displayed at a 1:50,000 scale and presented on a 1995 colour photo backdrop.

Data Analysis Required: Using information on species and stock presence by watershed (from FISS), the numbers of Red-listed and Bluelisted species (or stocks) can be identified for each watershed (Gustavson and Brown 2002).

Benchmarks: The greater the number of fish species endangered, threatened or vulnerable by watershed, the greater the risk to fish sustainability (Gustavson and Brown 2002).

Cost:

Pro:

Con:

Recommendation:

Appendix 1. References

Brown, D. and J. Dick. 2001. Environmental Monitoring: Business and Information Needs Study. Daryl Brown and Associates Inc. and Sustainable Visions.

Dent, L., H. Salwasser and G. Achterman. 2005. Environmental Indicators for the Oregon Plan for Salmon and Watersheds. Prepared by the Institute for Natural Resources for the Oregon Watershed Enhancement Board.

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Green Mountain Institute. 1998. Toward "A Small, but Powerful" Set of Regional Salmon Habitat Indicators for the Pacific Northwest. Prepared for the Pacific Northwest Salmon Habitat Indicators Work Group.

Gustavson, K. and D. Brown. 2002. Monitoring Land Use Impacts on Fish Sustainability in Forest Environments. Prepared for B.C. Ministry of Sustainable Resource Management, April 2002.

Knight and Piésold Consulting. 2002. Indicators of Fish Sustainability: Managed and Rare Fish in Forest Environments. Prepared for British Columbia Ministry of Sustainable Resource Management.

Oregon Watershed Enhancement Board (OWEB). 2003. The Oregon Plan for Salmon and Watersheds: Monitoring Strategy.

Ward, W.J. 1999. Pacific Northwest Salmon Habitat Indicators—Pilot Project, Snohomish River Basin. Prepared for the Washington State Department of Ecology.

APPENDIX 2. PREVIOUSLY ESTABLISHED SUITES OF INDICATORS

Eclipse Environmental Consulting Ltd. 1998. Workshop Report: Salmon Habitat Indicators and Data Sharing Workshop, Institute of Ocean Sciences, Sidney, B.C. April 22–23, 1998. Sponsored by the Fish Habitat Inventory and Information Sharing Working Group, Canada-B.C. Pacific Salmon Fishery Agreement.

1. Water Quantity / Water Quality

Issue / Indicator	**Comments**
1.1 Instream Flow—assessed water bodies with adequate flow to meet salmonid requirements, as measured by: % of waterbodies, # of waterbodies, % of particular stream classes meeting flow requirements	Ranked "High"
1.2 Temperature—assessed waterbodies where the maximum daily temperature causes: no potential moderate or severe impairment; potential impairment to sensitive species; moderate impairment; severe impairment	Ranked "High"
1.3 Chemical Water Quality Index—as measured by the B.C. Water Quality Index and Objectives of Aquatic Organisms	Ranked "High"
1.4 Toxic Contaminants—no indicator was identified, although the need for specialists to develop an indicator for this issue was emphasized	Ranked—"worthy of further consideration" due to its potential value in relation to fish health.

2. Land Use / Land Cover

Issue / Indicator	**Comments**
2.1 Land Use Conversion—# of acres in a watershed converted from one land use / land cover classification to other classifications	Ranked "High"
2.2 Effective Impervious Surface—% of impervious surface (roads, rooftops and parking lots) in a watershed	Ranked "High"
2.3 Slope Failures—# of failures, from the perspective of the watershed, not just adjacent to watercourses	Ranked "High" since the number of failures is very indicative of the state of the watershed
2.4 Channelization—km of stream channelized per geographical unit (not yet defined)	Ranked "High"
2.5 Wetland Area—undefined, but may be % wetland in drainage	Ranked "High"
2.6 Transportation Impacts—kms of road, by type, within one mile of historically anadromous salmonid streams, flood plains, and marine shorelines	Ranked "Medium" since it overlaps with 2.1, 2.2, 2.3
2.7 Road Crossings—not defined, but may include amount of mass wasting and/or # of land slide events	Ranked "Medium" since "Road Crossings" is too limited and does not include other physical impacts or other kinds of linear developments. It could be re-worded to be more inclusive.
2.8 Area Logged to the Stream Edge—undefined	There was agreement to add this to the land use indicator.

3. Physical Habitat

Issue / Indicator	**Comments**
Land / Water Complex	
3.1 Riparian Quality by Type—stream, lake, estuary, wetland, off-channel (side-channel)—as measured by total change in riparian area	All types ranked "High", except for "Estuary" which ranked "Medium"
3.2 Number Status of Streams—streams classified as endangered, threatened, wild or lost	Ranked "High"
3.3 Measure of Spawning Stock Strength—no indicator identified	Ranked "worthy of further consideration"
Impediments	
3.4 Barrier by Type—anthropogenic, natural	Ranked "High"
Morphology	
3.5 Stream Habitat Complexity—as measured by variance in thalweg depth	Ranked "High"
3.6 Channel Type and Condition—as measured by Channel Assessment Procedure (CAP)	Ranked "High"
3.7 Large Woody Debris (LWD) by Channel Type	Ranked "High"
Sediment	
3.8 Fate of Sediment in Stream Channel—no indicator was identified, this issue should be investigated by specialists	Ranked "High", as it is considered a key indicator.

Green Mountain Institute. 1998. Toward "A Small, but Powerful' Set of Regional Salmon Habitat Indicators for the Pacific Northwest. Prepared for the Pacific Northwest Environmental Indicators Work Group. 13p

Functional Category	Indicator
Fish Abundance	**1.1 Salmonids**—change in # of fish by life stage, by species
Water Quantity	**2.1 Instream Flow**—% of stream miles with instream flow meeting instream water rights, seasonal flow requirements for salmonids, and/or sufficient to allow salmonid access **2.2 Flow Hydrology**—% of waterbodies with minimal, moderate, extreme changes in hydrology from historical patterns (captures low and high flow extremes-deviation)
Water Quality	**3.1 Temperature**—% of assessed waterbodies where the daily maximum falls into: <10 degrees C—no impairment; 10–15 degrees C—potential impairment to sensitive species; 15–20 degrees C—moderate impairment; >20 degrees C–severe impairment **3.2 Biological Water Quality Index**—% of water rated excellent, good, fair, poor (possible parameters would include fish community and benthic macroinvertebrate species or taxa composition and richness using similar bioassessment protocols **3.3 Chemical Water Quality Index**—% of waters rated excellent, good, fair, poor (possible parameters would include temperature, dissolved oxygen, biological oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total suspended solids, and bacteria to produce a single number)
Land Use/Land Cover	**4.1 Land Use Conversion**—# of acres in a watershed converted from land use/land cover classifications (e.g., forestry, agriculture, rural residential, industrial, protected status, etc.) to other land use/land cover types over time with emphasis on floodplain to riparian area **4.2 Transportation Impacts**—miles of road by type *and road crossings* within one mile of historically anadromous salmonid streams, floodplains, and marine shorelines **4.3 Impervious Surface**—% of impervious surface (roads, rooftops, and parking lots) in a watershed
Physical Habitat	**The "habitat concept" includes four components:** **5.1 impediments/accessibility;** **5.2 morphology;** **5.3 sediment;** **5.4 land type adjacent to water (land-water complex).** **5.1.1 Impediments and Accessibility to Salmon Habitat**—# of locations where salmon are impeded, by type, and the *amount, by type,* of historically anadromous salmonid Pacific Northwest Salmon Habitat Indicators Work Group—May 1998 9 *habitat* rendered inaccessible by these impediments **5.2.1 Large Woody Debris**—Counts of debris pieces with lengths equal or greater than channel widths, noting presence/absence of root wads, per historically anadromous salmonid stream mile **5.2.2 Stream Depth**—variance of thalweg depths (flow path of the deepest water in a stream) **5.3.1 Sediment**—*change in* sediment loading rates **5.3.2 Spawning Area**—% change in spawning areas **5.4.1 Habitat Type Associated with Water**—the amount of habitat, by category (e.g., riparian forest, offchannel, wetland, estuary) associated with the margins of the water course in a watershed and the value of the habitat to the salmonid life-cycle

Ward, W.J. 1999. Pacific Northwest Salmon Habitat Indicators—Pilot Project, Snohomish River Basin. Prepared for the Washington State Department of Ecology.

Fish Abundance

1.1 Salmonids

Water Quantity

2.1 Instream Flow
2.2 Flow Hydrology

Water Quality

3.1 Temperature
3.2 Biological Water Quality Index
3.3 Chemical Water Quality Index

Land Use/Land Cover

4.1 Land Use Conversion
4.2 Transportation Impacts
4.3 Impervious Surface

Physical Habitat

5.1.1 Impediments and Accessibility to Salmon Habitat
5.2.1 Large Woody Debris
5.2.2 Stream Depth
5.3.1 Sediment
5.3.2 Spawning Area
5.4.1 Habitat Type Associated with Water

Gustavson and Brown, April 2002. Monitoring Land Use Impacts on Fish Sustainability in Forest Environments.

Strategic Level	Watershed Level
Road density	Landslide area density
Road density on steep slopes	Temperature
Road-stream crossing density on forest land	Turbidity
Road-stream crossing density on forest land on steep slopes	Habitat complexity
Equivalent clearcut area (ECA) density	Riparian disturbance
Riparian disturbance	Resident fish populations
Salmon escapement	Benthic macroinvertebrate diversity
Fish species at risk	

Knight Piésold Ltd. 2002. Indicators of Fish Sustainability: Managed and Rare Fish in Forest Environments.

Tier I—"Ready for use" relevant and sensitive indicators for which extensive B.C. data exist for some species, regions, or environments

- Temperature
- Instream flow(s)2
- Physical habitat3
- Chlorophyll *a*
- Nutrients

Tier II—Relevant, sensitive, and useful indicators for which existing data are limited.

- Benthic invertebrates

Dent, L., H. Salwasser and G. Achterman. 2005. Environmental Indicators for the Oregon Plan for Salmon and Watersheds. Prepared by the Institute for Natural Resources for the Oregon Watershed Enhancement Board.

- Coldwater Index of Biotic Integrity (combines measures of multiple biological indicators, such as species richness, relative abundance of specific organisms, and health of the organisms)
- Water Quality Index (Temperature, DO, Bacteria, Turbidity, pH, Phosphorus, Nitrogen, Nitrite, Nitrate, Ammonium Nitrate, Macro-invertebrates, BOD, Total Solids)
- Area, distribution and types of riparian and freshwater wetlands vegetation
- Riparian Function (based on vegetation and site capability)
- Condition of physical aquatic habitat and estuarine habitat
- Access to freshwater and estuarine aquatic habitat (km habitat accessible or limited)
- Conformance with instream flow requirements
- Area, distribution and change in area of tidal and submerged wetlands
- Index of Biotic Integrity for estuaries
- At Risk Species (aquatic and estuarine)

Norton-Arnold & Company. 2005. Wild Pacific Salmon Policy Forum: Summary Report. Forum Held: March 2 & 3, 2005. Submitted to Department of Fisheries and Oceans.

- Number of stream crossings
- Percentage of impervious surfaces
- Forest canopy
- Water temperature
- Bank stability
- Woody debris recruitment
- Water quality and quantity
- Minimum stream flow
- Wetlands

Tripp, D.B., P.J. Tschaplinski, S.A. Bird and D.L. Hogan. 2005. Protocol for Evaluating the Condition of Stream and Riparian Management Areas. FRPA Resources Evaluation Program, B.C. Min. For. And B.C. Min. Water, Land and Air Protection. Victoria, B.C.

The indicators used to assess riparian and stream channel monitoring include:

- channel bed disturbance
- channel bank disturbance
- LWD processes (jams)
- channel morphology
- aquatic connectivity
- fish cover diversity
- moss abundance and condition
- fine sediments
- aquatic invertebrate diversity
- windthrow frequency
- riparian soil disturbance
- LWD supply
- shade and microclimate
- disturbance-increaser plants
- vegetation vigour, form and structure.

Properly functioning condition as defined in the Forest Practices Code is the ability of a stream, river, wetland or lake and its riparian area to:

a. withstand normal peak flood events without experiencing accelerated soil loss, channel movement or bank movement;

b. filter runoff; and

c. store and safely release water

15 "Main" Questions

Question 1. Is the channel bed undisturbed?

Question 2. Are the channel banks undisturbed?

Question 3. Are channel LWD processes undisturbed?

Question 4. Is the channel morphology undisturbed?

Question 5. Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?

Question 6. Does the stream support a good diversity of fish cover attributes?

Question 7. Does the amount of moss present on the substrates indicate a stable and productive system?

Question 8. Has the introduction of fine sediments been minimized?

Question 9. Does the stream support a diversity of aquatic invertebrates?

Question 10. Has the vegetation retained in the RMA been sufficiently protected from windthrow?

Question 11. Has the amount of bare ground or soil disturbance in the riparian area been minimized?

Question 12. Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?

Question 13. Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?

Question 14. Have the number of disturbance-increaser plants or noxious weeds present been limited to a satisfactory level?

Question 15. Is the riparian vegetation within the first 10 m from the edge of the stream generally characteristic of the normal plant community?

APPENDIX 3. DATABASE DETAILS

Database Name	Data Provider Contact Information	Scale	Geog. Extent	Time Period of Data	Update and Main. Freq.	Cost	Meta-data	Description
Fish Inventory Summary System	B.C. Ministry of Sustainable Resource Management, Fish Inventory Summary System: http://www.bcfisheries.gov.bc.ca/fishinv/fiss.html	1:50,000	B.C.	1984–Present	Ongoing	No cost	Yes	The Fisheries Information Summary System (FISS) provides spatially represented summary level fish and fish habitat data for waterbodies throughout British Columbia and the Yukon. The information is in database format and can be displayed on the 1:50,000 Watershed Atlas. FISS is a jointly funded project by BC Fisheries and Fisheries and Oceans Canada. FISS is made up of data and map components. Fish and fish habitat themes included are fish distribution, enhancement and management activities and objectives, gradient and macro-reaches, land use, water use, water quality activities, obstructions, resource use, flow, fisheries potential and constraints, escapement, value and sensitivity, life history and timing, and harvest and use.
British Columbia Conservation Data Centre	The British Columbia Conservation Data Centre (CDC), http://srmwww.gov.bc.ca/cdc/	1:50,000	B.C.	1991–Present	Daily / Monthly	No cost	Yes	The British Columbia Conservation Data Centre (CDC) systematically collects and disseminates information on plants, animals and ecosystems (ecological communities) at risk in British Columbia. This information is compiled and maintained in a computerized database which provides a centralized and scientific source of information on the status, locations and level of protection of these organisms and ecosystems.
British Columbia Watershed Atlas	Aquatic Information Bank (Ministry of Sustainable Resource Management, Government of British Columbia), Bruce Mackenzie, (250) 387–4192, bruce.mackenzie@gems7.gov.bc.ca	1:5,0000, some at 1:20,000	B.C.	N/A	Varies	No cost	Yes	The Watershed Atlas is a digital representation of the stream network of British Columbia as depicted on 1:50,000 National Topographic Series maps along with watershed boundaries of 3rd order and larger watersheds. The Watershed Atlas is organized into 246 watershed groups that were originally assembled based on natural watershed groupings and size.

Database Name	Data Provider Contact Information	Scale	Geog. Extent	Time Period of Data	Update and Main. Freq.	Cost	Meta-data	Description
Terrestrial Ecosystem Modeling / Predictive Ecosystem Modeling	B.C. Ministry of Sustainable Resource Management, Ecology, http://srmwww.gov.bc.ca/ecology/tem/	Varied	Project by Project basis	Varied	N/A	N/A	N/A	Terrestrial Ecosystem Mapping is a methodology which requires direct air photo interpretation of ecosystem attributes by a mapper(s). This approach is typically used at larger scales where more detailed information is required. For situations where less detail is preferred (i.e., smaller scales), the Predictive Ecosystem Mapping approach is used. PEM is a modeled approach to ecosystem mapping, whereby existing knowledge of ecosystem attributes and relationships are used to predict ecosystem representation in the landscape.
Baseline Thematic Mapping	Government of British Columbia, Ministry of Sustainable Resources, Digital Atlas: http://srmwww.gov.bc.ca/bmgs/catalog/digatlas.htm	1:250,000	B.C.	1995–Present	Ongoing	$250 / public	Yes	Baseline Thematic Mapping (BTM) products product is a digital thematic map depicting Land Use at a scale of 1:250 000. The digital files are Geographic Information System (GIS) compatible and are available from LandData BC and include 20 land use classes defined for the Province of B.C.
Vegetation Resource Inventory	Government of British Columbia, Ministry of Sustainable Resources, http://www.for.gov.bc.ca/hts/vri/	Varied	Project by Project basis	N/A	Ongoing		Yes	The Vegetation Resource Inventory was developed by the B.C. Ministry of Forests and Range. This inventory describes forestry resource location and types; however, full coverage of B.C. is not yet available.
National Forest Inventory	Government of British Columbia, Ministry of Sustainable Resources, http://www.for.gov.bc.ca/hts/nfi/	Varied	National	N/A	Ongoing		Yes	The National Forest Inventory is available through the B.C. Ministry of Forests and Range. This inventory was developed to provide the province the ability to report nationally on the current status of the forest resource in B.C. and to monitor changes in the forest. This inventory closely parallel's the Vegetation Resource Inventory attribute information and is incorporated into the National database.
Floodplain Mapping Program	Government of British Columbia, Ministry of Sustainable Resources, http://srmwww.gov.bc.ca/aib/fpm/	Varied	B.C.	N/A	N/A	No cost to download image files (.JPGs)	N/A	The Floodplain Mapping Program was a joint initiative by the federal and B.C. governments to provide information to help minimize flood damage in British Columbia. The program identified and mapped areas that were highly susceptible to flooding. These areas were designated as floodplains by the federal and provincial Environment Ministers

Database Name	Data Provider Contact Information	Scale	Geog. Extent	Time Period of Data	Update and Main. Freq.	Cost	Meta-data	Description
Water Survey of Canada Data	Environment Canada, Water Survey of Canada, http://www.wsc.ec.gc.ca/products/main_e.cfm?cname=products_e.cfm	N/A	National	1850–Present	Annually	Varies	N/A	Currently there are over 500 Water Survey Hydrometric Stations in B.C. that provide data on water flow, water level, sediment concentration or sediment load, and water temperature. Past data since 1970 are available for 2400 stations in B.C. from Environment Canada; however, sampling station location and frequency is likely poorly suited to status and trend monitoring.
Digital Terrain Mapping	Government of British Columbia, Ministry of Energy, Mines, and Petroleum Resources, http://www.em.gov.bc.ca/Mining/Geolsurv/Terrain&Soils/Default.htm	1:1,000 to 1:1,000,000	B.C.	N/A	Irregularly	No cost	Yes	The Digital Terrain Map Library provides terrain and slope stability related maps in digital format. The digital maps may be constructed and viewed on-line or downloaded for use in a GIS or Desktop Mapping package. The project is operated by the Geological Survey Branch of the Ministry of Energy and Mines and funded by Forest Renewal BC.
Digital Elevation Model	Government of British Columbia, Ministry of Sustainable Resources, Digital Atlas: http://srmwww.gov.bc.ca/bmgs/catalog/digatlas.htm	25m	B.C.	N/A	Ongoing	$500.00	Yes	A 25 metre gridded DEM product produced from the Triangulated Irregular Network (TIN) that is part of the TRIM product. Each gridded DEM combines 100 TRIM mapsheets into a 1:250,000 quad (such as 92G.grd) Elevations are stored as pixels in signed 16 bit integer binary format. Also available in USGS or ESRI ASCII grid formats.
TRIM	Government of British Columbia, Ministry of Sustainable Resources, Digital Atlas: http://srmwww.gov.bc.ca/bmgs/catalog/digatlas.htm	1:20,000	B.C.	N/A	Ongoing	Varies according to product	Yes	Collection of five data sets: digital elevation model (DEM), raw contours, planimetric positional data (roads, rivers etc), toponymy data, non positional data (heights), and additional feature codes from the Data Exchange Program. Compiled digitally at 1:20,000 utilizing mid-scale level (1:35,000 and 1:40,000) vertical air photos from 1995 to the present. NAD 83.
Community Mapping Network	Community Mapping Network website: http://www.cmnbc.ca/	Varied	B.C.	Varied	Varied	Free	Yes	The Community Mapping Network is a website developed through a collaborative effort involving a number of federal and provincial government departments, as well as non-governmental organizations. The purpose of the website is to integrate community and government natural resource information using an interactive web-based GIS.

Database Name	Data Provider Contact Information	Scale	Geog. Extent	Time Period of Data	Update and Main. Freq.	Cost	Meta-data	Description
Coastal Resource Information Management System	Coastal Resource Information Management System, http://srmwww.gov.bc.ca/dss/coastal/crimsindex.htm or http://maps.gov.bc.ca/imf406/imf.jsp?site=dss_coastal	Varied	B.C.	Varied	Ongoing	Free	N/A	The British Columbia Coastal Resource Information System is an internet based interactive map for viewing coastal and marine data. A wide variety of coast and marine resources are included, such as aquaculture, shoreline classification, selected fisheries information, and offshore oil and gas information.
Committee on the Status of Endangered Wildlife in Canada	Committee on the Status of Endangered Wildlife in Canada, http://www.cosewic.gc.ca/eng/sct1/searchform_e.cfm	N/A	National	Varied	Ongoing	Free	N/A	Committee on the Status of Endangered Wildlife in Canada provides access to a searchable database of Species At Risk.
British Columbia Digital Road Atlas	British Columbia Digital Roads Atlas, http://srmwww.gov.bc.ca/bmgs/dra/index.html	Varies	British Columbia	Varied	Ongoing	Varies according to product	Yes	The Digital Road Atlas (DRA) is a data management system representing a complete and accurate road network of all the roads in British Columbia. Through the active participation and support of the DRA Partners, the data in the DRA has been compiled from multiple existing sources, such as TRIM, Ministry of Forest resource roads and Ministry of Transportation highway information. An update mechanism that works with each source of data ensures the DRA remains current and relevant. Data errors are reported by users via a web-based application to complete the feedback loop and continually improve the data.
Satellite Imagery	British Columbia Satellite Image Registry / Individual Data Providers (such as Space Imaging).	Varied	Varied	Government of British Columbia: 1990–Present, Other data providers: Varied	Ongoing	Varied	Yes	

APPENDIX 4. EXPERT TECHNICAL WORKSHOP REPORT

Expert Technical Workshop on Wild Pacific Salmon Habitat Indicators

Held in Vancouver, B.C.

November 17, 2005

Prepared for:
Pacific Fisheries Resource Conservation Council

Prepared by:
G.A. Packman & Associates Inc. and Winsby Environmental Services

Project Number: GP 05134
February 6, 2006

1.0 Introduction

This report presents the results from a workshop held by the Pacific Fisheries Resource Conservation Council (PFRCC) in Vancouver, on November 17, 2005, to review the use of habitat indicators for assessment of habitat status for wild Pacific salmon.

The PFRCC is an independent Council established to provide advice and information to federal and provincial fisheries ministers and the general public regarding the conservation of Pacific fisheries resources. Fisheries and Oceans Canada (DFO) released "Canada's Policy for Conservation of Wild Pacific Salmon" (the Wild Pacific Salmon Policy) in June 2005. The PFRCC views the Wild Pacific Salmon Policy as a positive development in the stewardship of Pacific fisheries resources and would like to support and facilitate its successful implementation.

A key component of the Wild Salmon Policy is the conservation and stewardship of habitat for wild Pacific salmon. In order to focus and support habitat conservation and stewardship efforts, a suite of indicators at a range of geographic scales is needed. Strategy 2 of the Wild Pacific Salmon Policy outlines action steps to be taken for assessment of habitat status. This workshop was held as part of a project intended to assist the PFRCC in providing advice and support to DFO on indicators of the status of wild Pacific salmon habitat.

In preparation for the workshop, background information was compiled in the form of a draft summary report on wild Pacific salmon indicator development. This Main Report provided an overview of the chronology and state of habitat indicator development for wild Pacific salmon, and provided details and preliminary analysis on a suite of habitat indicators to illustrate a process for developing/selecting candidate indicators. This Main Report was circulated to participants in advance of the workshop. The Main Report has been updated to reflect workshop results and constitutes the main report to which this workshop report has been appended.

The purpose of the November 17, 2005 workshop was to:

- Obtain feedback on the information compiled in the Main Report; and
- Build consensus on
    - Information availability;
    - Approaches to selecting and implementing candidate indicators;
    - Requirements for additional information; and
    - Feasible next steps to develop indicators further and facilitate effective implementation.

The workshop agenda is presented in Appendix 1 to this workshop report. A list of workshop participants is presented in Appendix 2. The slides used in presentations made at the workshop are contained in Appendix 3. All workshop deliberations were facilitated in plenary.

2.0 Review of the Information Base

The information presented in the Main Report was reviewed in a slide presentation (Appendix 3) to provide a basis for workshop discussions. Discussions during the presentation were encouraged and presentation slides were used to focus discussions during later stages of the workshop.

The presentations also included a presentation by Dr. Jim Irvine (Appendix 3) on the Conservation Unit (CU) concept that forms the backbone of the Wild Pacific Salmon Policy, and its development and application.

2.1 Discussion Surrounding the Information Base

The two presentations led to considerable discussion about application of the CU concept with respect to wild Pacific salmon, the role of habitat indicators, and the current state of indicator development. Points raised in these discussions played a pivotal role in shaping the direction and approach to later sections of the workshop agenda. An overview of points raised and related discussions is presented below.

It is notable that, at the outset, there was a strong collective view that consideration of habitat change and indicators needs to be directed by a fish-centric perspective. A fish-centric perspective should be reflected in analysis supporting indicator selection, as well as in implementation.

Indicator Selection Model: Pressure-State-Impact-Response (PSIR)

The Main Report and presentation indicated that the PSIR Model for indicator selection is the most commonly used approach.

Definitions for the components of the PSIR Model are presented below:

- "Pressure" indicators reflect the sources and types of pressure or stress that are, or may be, imposed on fish habitat.
- "State" ("Status", "Condition") indicators reflect the current characteristics of the habitat itself.
- "Impact" indicators measure the impact from "Pressure" on the medium under consideration.
- "Response" indicators are used to track the responses to "Pressures" and "Impacts" to improve the "State".

These are further discussed in Section 3.2 of this Expert Technical Workshop Report.

Participants raised the following points in relation to the PSIR Model:

- Concerns were raised, although not by all participants, that the PSIR Model may not be sufficiently fish-centric, particularly with respect to potential "Pressure" indicators (e.g., Landuse Conversion).
- There were suggestions; however, that the PSIR Model could be applied if attention was paid to ensuring that application is from a fish-centric perspective.
- It was also recognized that "Pressure" indicators provide insight into areas to look for habitat change and insight into the underlying reasons for change to facilitate development of appropriate management response.
- As an example, in the case of habitat indicators related to forestry, a rationale linking change in forest cover or riparian vegetation should be developed to substantiate and confirm use of the "Pressure" indicator in terms of a fish-centric perspective (e.g., What is important to fish is Temperature and Sediment regimes, and the removal of trees is expected to alter these in a way that would affect salmon production).
- Participants agreed that there is extensive information linking forest harvesting to effects on fish so, with proper rationales, "Pressure" indicators as identified through the PSIR Model approach would make an effective contribution.
- Ms. Risa Smith indicated that while most indicator selection exercises seem to use the PSIR Model, this Model is often applied simply because most of the previous reference documents had referred to it. She indicated that other models have been used for State of the Environment reporting and may warrant some consideration.

Habitat Indicators and CUs

The Main Report introduced the concept of CUs and related habitat indicators for wild Pacific salmon. As noted above, Dr. Irvine presented a more in-depth overview of CUs, the process being implemented by DFO for defining CUs, and related habitat considerations. The presentations engendered considerable discussion, from which the following key points were derived.

- To meet information needs for the anticipated CU sizes and limits, the provincial information bases provide the useful information with the following qualifiers:
    - Strategic level information is available from across the province; however, this information is derived from other programs and is not specifically driven by the information requirements of salmon CU management;
    - Provincial information bases should be able to support the consideration of indicator or pilot watersheds; and
    - The information bases may not have the required level of detailed information to support development or tracking of habitat indicators at the site level.
- Habitat indicators should be applicable at the full range of life history stages for each of the different species.
- It will be important not to confuse Habitat Units with CUs.
- Habitat condition is linked to other natural influences such as climate change, flooding, etc. and not just anthropogenic change.
- In terms of information use, application of habitat indicators will need to be at the level of the watershed as well as the CU level. It should be possible to extrapolate from CU level indicators to the watershed level; however, some indicators (e.g., flow) may only be fully functional at the watershed level.

- It will be important to consider the level at which the information derived via the indicators will be communicated. Indicators for communication at the policy level may differ from indicators designed for communication and use at the technical and scientific levels.

Linkages between Habitat and Wild Pacific Salmon Production

Discussion during Dr. Irvine's presentation included the following points related to linking habitat and wild Pacific salmon production:

- There may be trade-offs between indicator effectiveness and practicality/data availability. For example, sea surface temperature anomalies in the ocean show a good relationship with survival, growth and returning salmon. On the other hand, in freshwater, temperature on its own may not be the best indicator but it is easy to monitor and obtain reliable data.
- A direct relationship between number of fish and riparian vegetation may not be as strong as needed. The result from changes in riparian vegetation may, however, manifest itself as increased temperature throughout the watershed. To document changes in habitat and production, statistical linkages between the two should be sought.
- There is a need to exercise caution in linking freshwater habitat indices to fish productivity, in light of evidence showing that marine habitat and production have a strong linkage to overall wild Pacific salmon production.
- More definitive causal linkages, supported by statistical links, can be established through a number of credible studies. Statistical linkages alone should not be relied upon.
- There is a need for considerably more detailed information on problems at different life history stages and differences in life history patterns, in order to better define what is limiting/controlling production at each life history stage.
- One approach to gaining a perspective on habitat condition, and tracking condition over time, is to develop multiple habitat "envelopes" that capture preferred habitat conditions for species, life history stages and geographic areas. These could be simple or quite complex, but would provide a frame of reference for monitoring data indicating where existing habitat conditions sit with respect to an overall habitat preference "envelope". The validity of such multiple habitat condition envelopes would need to be verified scientifically.
- Habitat indicators to support CU management are intended to reflect an empirical approach rather than a theoretical approach.
- If the focus is on detecting and tracking changes to habitat status for a CU, then it might not be necessary to have definitive links to productivity, particularly if a series of habitat benchmarks is established.

Implications for Selection of Habitat Indicators: Expectations

Discussion during Dr. Irvine's presentation also included the following points related to implications and expectations associated with selecting habitat indicators:

- The overall intent is to preserve Canada's natural capital in terms of fish and the capability to produce them, recognizing that we may not have the capability to clearly define the link between habitat and production. We do, however, know that high quality habitat does support wild Pacific salmon production.
- The expectations are that indicators will:
    - Support management to conserve fish;
    - Serve as a warning signal that management can respond to; and
    - Build public knowledge and support in terms of overall status and what is needed in watersheds.

- In developing a suite of indicators, it is important to realize that there are some environmental stresses at the ecoregion scale that fisheries and habitat management will not be able to do anything about. These environmental factors include de-forestation caused by mountain pine beetle, and effects from climate change such as changes in precipitation patterns.
- Another objective of Wild Pacific Salmon Policy is to develop benchmarks once the thresholds have been developed. It was noted that, once 'Red Zones' are established, public perception will be high and DFO action will have a corresponding degree of visibility.
- An argument for tracking "Pressure" indicators stems from the need to establish the appropriate management response once a problem is identified with "State" indicator. For example, if temperature affecting a CU increases, in order to develop and implement a management response it will be necessary to know the cause of the temperature increase (i.e., whether it is riparian vegetation removal due to logging or mountain pine beetle; disruption of groundwater inputs; etc.)

Practicability of Indicator Selection to Meet Habitat Status Assessment Needs:
The following points were raised in a general discussion on the inter-relationship between fisheries management and habitat management on a CU basis:

- Some participants indicated concern that the indicator selection process could be too simplified to identify indicators suitable for broad application at a number of geographic scales, and for different environments and habitat types.
- Participants agreed that there is a need to focus on the components of an "indicator system" because it will be difficult to afford many indicators or systems.
- It was noted that it will be difficult to link habitat indicators to stock assessment activities because it may not be possible to monitor all required indicators or systems at the level of detail that would be required.
- There will likely be a need for indicators at more than one geographic scale. In this regard it would be beneficial to use an adaptive management approach to indicator development, to implement, learn and adjust as lessons are learned. In addition to drawing on references in the Main Report, it would be beneficial to take advantage of any additional lessons learned in the United States, recognizing that other factors may also have influenced choices in the United States. In the United States, a number of findings suggest that broad scale application of indicators is useful.
- It was emphasized that indicators under the Wild Pacific Salmon Policy are not intended to be a program to look at impacts from specific industrial projects.
- It will be important to ensure that expert technical specialists have input to the development of indicators, to ensure that the questions asked and information provided will be useful to provide feedback on the state of wild Pacific salmon habitat in support of CU management. Expert technical specialists can provide information on the appropriate geographic scale for indicator selection / implementation, information requirements, etc.

Data Reliability versus Availability

In a general discussion on the importance of selecting indicators for which data are considered reliable and available, the following points were raised:

- It was agreed that for each indicator selected, there is a need to analyse and consider the appropriate geographic scale for the indicator, the methods that would need to be applied in gathering data, the expected reliability of the data that would be gathered, and the availability of data from historic data sources or from other jurisdictions and programs.
    - As an example, the point was made that benthic macroinvertebrate indicators, although possibly limited in the geographic scale to which they can be practically applied, could be included as sub-components of broader studies. The point was made that the Canadian Aquatic Biomonitoring Network (CABIN) provides a basis for collaboration and should be investigated further as part of any indicator selection/implementation initiative.
    - It was agreed that an indicator such as "number of dams" in a system would be a fairly straightforward indicator at the watershed scale for which reliable data would be readily available.
- Some concerns were raised to the effect that some indicators have not been shown to work elsewhere and evidence will be needed to confirm that indicators will work before they are selected.
- The process of indicator selection should consider a number of fundamental questions:
    - What is the appropriate geographic scale of application for the indicator?
    - Why is a status indicator necessary? In other words, what will information from the indicator provide that will support CU management?
    - What is the current status?
    - Where is that status situated in terms of trends and cycles?
    - What is the maximum yield from a watershed? Some participants expressed a certain degree of frustration over difficulty in linking habitat indicators to maximum yield. It was noted that the changes in habitat and fish stocks resulting linked to a dam in a watershed provides an extreme example of the difficulty.
- The point was made that a number of state of the environment indicator programs are in existence and are available from a "lessons learned" perspective.

Indicator Feasibility / Cost / Benefit

In a general discussion on habitat indicators for wild Pacific salmon, the following points were raised in relation to the practical benefits to be derived, in relation to CU based salmon production:

- Some participants suggested that freshwater habitat is not as relevant to production as effects occurring in marine areas, while others argued that effects in marine areas are not as relevant to production as those occurring in freshwater. This creates a challenge in selecting reliable habitat indicators to support CU management.
- The point was made that scientists generally shy away from indicators, in light of the potential for oversimplifying what can be quite complex relationships.
- It was recognized that, in light of a goal of improving the management of fisheries, a suite of indicators may not be perfect but would provide a tool that would enable management to move in the right direction.
- Developing and testing a set of simple indices, over a period of years, would help to address this issue.

- It will be necessary to develop the indicators and prove that they are useful from a scientific perspective. This would help to separate out some of the myths around indicator selection.

In accordance with findings in the Main Report and Dr. Irvine's presentation, all participants agreed that applicable indicators have, for the most part, been reviewed, selected and implemented to a certain degree previously, in various applications. It was agreed that the background information leads to a conclusion that the critical steps in establishing an indicator program such as the one called for in the Wild Pacific Salmon Policy, include selection of specific indicators for specific applications and geographic scales, and the implementation-definition step that moves from strategy into successful implementation of a monitoring program utilizing the identified indicators.

This collective recognition by participants led to a shift in the workshop approach toward the identification of steps required to successfully develop and implement a suite of wild Pacific salmon habitat indicators in support of the Wild Pacific Salmon Policy. The process for doing so, however, included discussion of a suite of specific indicators, in order to explore approaches associated with indicator selection, and steps needed to move into implementation. The following sections of this report, document these workshop discussions.

3.0 Discussion of Indicator Selection and Implementation

Workshop participants discussed the purpose of habitat indicators in relation to the assessment of wild Pacific salmon habitat "State", and general types of habitat "State" indicators in the context of the Pressure-State-Impact-Response model, and types of indicators.

3.1 Purpose of Habitat Indicators

Participants discussed and agreed that the purpose of habitat indicators for wild Pacific salmon should be to:

- Establish the status of habitat and track habitat quality over time;
- Relate habitat status to the to habitat preference/acceptability envelopes for species and life stages discussed above, with a view to having the maximum number of fish in the widest array of habitats. It was recognized that establishing benchmarks for habitat suitability/acceptability will be a challenge;
- Support management and conservation of the resource;
- Influence policy both with respect to pressures on habitat as well as fisheries management; and
- Foster public awareness of the factors that influence salmon production and their relative importance.

Participants discussed and agreed that information about habitat gained from implementation of indicators could be used to:

- Characterize the "State" of habitat and direct a management response (e.g., habitat conservation/restoration; fisheries management);
- Support the identification of needs and/or opportunities for habitat restoration initiatives and support their implementation;
- Put into context overarching natural changes in environmental conditions to support the development and implementation of management responses; and
- Roll-up findings into summaries at different spatial scales to support a variety of analyses.

It was agreed that the objectives and expectations associated with habitat indicators need to be clearly established. Some considerations around this included:

- There is a need to be clear on the expected geographic scale of application for indicators, both collectively and individually (i.e., specify whether an indicator is applicable at the regional, watershed, CU or site specific level);
- There is a need to be clear on the objectives of indicators (e.g., assessing current "State", or change/trends over time—both are needed);
- It will be a challenge to evaluate trends or changes in status over time (e.g., challenges in maintaining data collection; inter-comparability; and consistent, appropriate and robust statistical design);
- Linking indicators to fish production is more complex than tracking changes in habitat suitability;
- It would be preferable to envisage habitat as a box (envelope) of suitability/acceptability in a multidimensional space, which really means a whole series of boxes as fish move through their life history;
- By considering fish only, the focus may be too narrow. There may be advantages to considering more than fish. It would be preferable to broaden the vision for indicators to include the condition of other biota; however, the DFO mandate really focuses on salmon habitat. Opportunities for collaborative efforts should be sought;
- Indicator selection should take into account the intended audience for "State" reporting. For example, scientific and operational staff may use results from one type of indicator/analysis, while policy-makers may use another. The needs of the public, and associated communications, will also have to be taken into account; and
- The approach to indicator selection and implementation should be flexible, in order to roll-up into an appropriate range of geographic scales.

Relationship to Strategic Elements of the Wild Pacific Salmon Policy

Workshop participants briefly discussed the relationship between habitat indicator selection and use, and other strategic elements of the Wild Pacific Salmon Policy. Key points from that discussion are summarized below:

- In order to preserve genetic diversity, the intent will be to conserve habitat to enable the maximum number of fish to be productive in the widest possible array of habitats, within a strategic planning context; and
- Strategy 3 of the Wild Pacific Salmon Policy in part addresses the question: What can 'salmon' do for the habitat and other components of the ecosystem such as riparian, terrestrial, stream/lake productivity. This relates to the implications that escapement has for other components of the environment. Current investigations by ESSA Technologies, under contract to the PFRCC, are using an approach whereby conceptual models are being developed based on a literature review of linkages between returning salmon and other ecosystem components. The work will be potentially useful for examination of habitat components.

3.2 Types of Habitat Indicators

Recognizing that considerable work has been done in relation to the development of indicator lists for a variety of settings and applications, participants explored a process for moving forward toward effective implementation by reviewing select types of indicators that are desirable, in the context of the Pressure-State-Impact-Response model. The intent of reviewing the PSIR model was not specifically to develop the model for application in the case of the Wild Pacific Salmon

Policy, but to provide a common context for indicators under discussion, to facilitate subsequent discussions on the selection of a range of indicator types.

Pressure Indicators

"Pressure" indicators reflect the sources and types of pressure or stress that are, or may be, imposed on fish habitat. Comments related to this category of indicators included:

- It is important to recognize that, for land based "Pressure" indicators, there can be a lag time that can be in the order of 10 years between a human activity causing a "Pressure", and an effect on fish;
- Uncertainty exists in the extent of linkages between "Pressure" as evidenced by an indicator and changes in habitat variables and ultimately changes in fish production. Scientific challenges often arise related to location and linkages to certain types of activities;
- "Pressure" caused by human stressors can be removed by policy actions;
- "Pressure" arising from natural stressors (e.g., climate change, mountain pine beetle infestation and fire) need to be included but are much more difficult or perhaps impossible to address; and
- "Pressure" and other indicators from the PSIR model should be looked at together, as a suite.

State (Condition) Indicators

These indicators measure and track the "State" ("Status", "Condition") of habitat. Comments related to this category of indicators included:

- "State" indicators are the ones that people are generally most familiar with and are most clearly linked to fish;
- As discussed above, translating information derived from "State" indicators into wild Pacific salmon production will be difficult. The information derived from these indicators would, however, be useful (essential) to inform conclusions on management actions;
- The timescale for "State" indicators provides an important (essential) context for information gathered:
    - Baseline information is essential to document the current "State" and provide a basis against which to track future trends; and
    - When selecting a "State" indicator, it is necessary to determine the current availability of information to support indicator application, and/or the anticipated availability of information in the future. Costs of data gathering and management are an important consideration.
- Benchmarks are needed against which trends can be evaluated. It may be possible to utilize the baseline as a benchmark in "pristine" situations and/or situations where benchmarks are not available or difficult to establish; and
- Participants conceptually agreed upon some basic "State" indicators, that would include:
    - Temperature;
    - Flow/Hydrology;
    - Instream habitat—where and how much;
    - Number of streams; and
    - Number of streams with wild Pacific salmon life stages.

Impact Indicators

"Impact" indicators measure the impact from "Pressure" on the medium under consideration. There was some questioning and debate among workshop participants over what exactly

"Impact" indicators are. The observation was made that "State" indicators, if tracked over time and used to develop trends, are really tracking the impacts that derive from "Pressure" indicators.

It was decided that, spending time to develop a series of "Impact" indicators, distinct from "State" indicators might not be a completely productive use of the workshop time.

Ultimately participants agreed that the most meaningful indicators of "Impact" derived from changes to habitat, would be changes in the abundance of fish at each life stage in each habitat type.

Response Indicators

"Response" indicators are used to track the responses to "Pressures" and "Impacts" to improve the "State". These are most likely to be management responses, but could also be natural ecosystem responses.

Participants agreed that some candidate "Response" indicators could include:

- Number, types and locations of habitat restoration projects/activities;
- Integrated planning initiatives;
- Improvements in land use;
- Improvements in fish passage;
- Improvements in regulated flow regimes;
- Fisheries and habitat components of CU management plans;
- Shifts in biotic community structure, including fish communities;
- Etc.

Overall, while participants arrived at a common appreciation for the context of specific types of indicators within the PSIR model, it would be fair to say that participants did not consider that a lot of time should be spent on developing the model further. They did, however, apply contextual guidance derived from discussion of the PSIR model to facilitate discussions on specific indicators presented below in Section 5 of this report.

4.0 Habitat Indicators: Selection and Implementation Strategy

Participants recognized that the literature has indicated that implementation of a suite of indicators has been the most challenging aspect of past wild Pacific salmon habitat indicator initiatives. Accordingly, participants engaged in discussions regarding a preferred process for indicator selection that would foster and facilitate downstream adoption and development of institutionalized programs that would provide for successful implementation. Aspects considered in this discussion included:

- There is a need to identify and build concensus around the preferred characteristics of indicators that should be incorporated into the selection process; and
- There is a need for identification of, and concensus around, the pros and cons of individual indicators.

4.1 Process for Indicator Selection

Workshop participants discussed the process for indicator selection and agreed upon the following key elements:

- Develop a preliminary list of habitat indicators based upon those most commonly identified in previous processes as reported in the literature, and from ongoing monitoring and research;
- Narrow this list down to a shortlist through a screening process that includes the elements listed below for detailed analysis;
- Complete a detailed analysis for each candidate indicator on the shortlist.
- The detailed analysis should include aspects such as:
    - The indicator provides useful information in the context of the PSIR model (or other selected model);
    - Definition of the indicator;
    - Geographic scale to which the indicator applies (e.g., ecoregion, watershed, site specific, etc.);
    - Species to which the indicator applies;
    - Life history stage(s) addressed;
    - Rationale for linkages to a fish-centric perspective;
    - Methodology for data collection is established, currently in use, straightforward and robust;
    - Indicator is currently in use and data are being collected and managed;
    - The data are available and are of an appropriate quality;
    - Degree of data analysis required;
    - Cost is not prohibitive;
    - Pros;
    - Cons; and
    - Overall, implementation is considered effective and feasible/not feasible.
- Participants strongly recommended that the detailed analysis should involve input from a range of individuals to provide relevant scientific, management, policy, and data management input; and
- The detailed analysis should be summarized into a matrix from which a suite of indicators can be selected.

Once a suite of indicators has been identified, then a detailed plan for delivering on next steps toward implementation can be developed.

The suite of indicators should be directed toward quantifying the amount of habitat that falls within the preference "envelope" for each life history stage. Participants agreed that this could be accomplished through measurement on a representative sample and extrapolation through a model type of approach; however, the detailed methodology would have to be developed through inter-disciplinary collaboration.

4.2 Barriers to Implementation

Recognizing that the transition from indicator selection to effective implementation is a key step that has proven difficult in the past, participants listed what would be considered barriers to implementation. The barriers identified, based upon previous studies and experience, included:

- There is a lack of habitat mapping at an appropriate scale, meaning that the baseline for future comparison is not complete;
- Some indicators may be too specific to provide the required level of information to enable an appropriate management response;
- Some indicators may be too expensive to implement widely;
- Methodologies may not be sufficiently robust;
- Inadequate data management capability, meaning that key data could not be easily accessed electronically by all parties and may not be georeferenced;
- Cooperative arrangements with partners are not clearly established and committed to through formal arrangements with resource commitments, timeframes, etc.;
- Lack of management commitment;
- Lack of resources, or inadequate resources;
- Lack of data inter-comparability;
- Etc.

Selection and implementation of a suite of indicators for wild Pacific salmon habitat will need to address these barriers proactively and collaboratively through the selection process.

4.3 Development of a Shortlist of Candidate Indicators

Workshop participants discussed development of a short list of candidate "State" indicators. In the course of this discussion, participants agreed that there is also need for "Pressure" indicators that capture the implications of each relevant industrial/ development sector. Forestry and agriculture were identified specifically for inclusion, but not necessarily to the exclusion of others, and not to the exclusion of municipalities. It was noted that, in addition to the programs referenced in the Main Report, a program has been implemented in the Okanagan using EMAP (Environmental Monitoring and Assessment Program) methods from the U.S. Environmental Protection Agency and includes monitoring parameters such as hydrometric and chemical parameters, as well as benthic macroinvertebrates.

Workshop participants discussed the factors/criteria that should be considered in a multi-disciplinary evaluation of the suitability of candidate indicators for inclusion on a shortlist. These factors/criteria are listed and discussed below.

- ***Relevance to***
    - Wild Pacific salmon (species and life history stages) and beyond salmon
    - Policy
    - Management
    - First Nations
    - Public
- ***Scientific validity***
    - There is a link to wild Pacific salmon production (species and life history stages)
    - Standard methodology, protocols and QA/QC are available

    - Amendable to statistical analysis
    - Robust
- ***Input data***
    - Baseline data are available
    - Data are currently available and will be available on a continuing basis through an existing program
    - Data are not inordinately expensive to collect
    - Data medium and format (paper files, reports, electronic, in format that facilitates integration with other data)
    - Reliability of the data
        - Supported by appropriate data collection protocols and QA/QC procedures/documentation
        - Metadata are available and accessible
    - Data are readily accessible
    - Robustness
    - Reflects both short/longterm response and trends
    - Indicator data do not have a lag time that compromises effectiveness and/or utility
    - Data are amenable to providing appropriate geographic scale of coverage at the Broadscale, Sentinel and Detailed Study levels
- ***Applicable scale***
    - Data are available at the appropriate geographic scale (Broadscale, Sentinel, Detailed Study) to provide insight into wild Pacific salmon production at the CU level
    - Data can support decisions at both the strategic and site specific levels
- ***Status or trend applicability***
    - Timeseries data are available
    - Database is updated at appropriate time intervals
- ***Data management considerations***
    - A database update process exists and is supported by QA/QC procedures, metadata, etc.
- ***Overall feasibility***

It was recognized, that a considerable amount of progress in indicator evaluation had already been made in Appendix 1 of the Main Report. It was agreed that, in order to foster adoption of indicators and development/implementation of programs to operationalize them, it would be preferable to engage in a multi-disciplinary approach to indicator analysis, selection and rationalization to complete the process started in Appendix 1 of the Main Report. There was insufficient time in the workshop to complete this task; however, a start was made to test the approach. Results from this exercise are presented below in Section 5.0.

5.0 Comments on Specific Candidate Habitat Indicators

In order to quickly test the habitat indicator selection process in the workshop, participants developed a shortlist of candidate indicators, drawing on the shortlist presented in the Main Report, as represented in the initial workshop presentation (Appendix 3). Participants completed a cursory analysis for each candidate indicator considered. Not all criteria were evaluated due to time constraints; however, it was possible to gain an appreciation for the type of process that would be appropriate. Results from this exercise are summarized below.

Temperature

Participants agreed that "Temperature" is an important indicator to include. The temperature preferences of wild Pacific salmon are generally well understood; however, the implications for CU production associated with moving to less preferred ranges within the temperature tolerance envelope are not well understood for all life stages. Reliable data can be obtained relatively inexpensively using data loggers and are already being obtained through existing programs (e.g., existing hydrometric stations). The density of current data coverage is not adequate to identify CU production limitations, and a tiered approach to data gathering at different geographic scales would likely be appropriate (i.e., Broad-scale, Sentinel and Detailed Study).

It was noted that "Pressure" indicators such as "Landuse Conversion" can provide useful information to extend the utility of "Temperature" data coverage by indicating areas where temperature increases might occur and areas where riparian vegetation is such that temperature reductions can be expected to occur.

Instream Flow and Hydrology

Participants agreed that flows and the hydrological cycle are essential to fish survival and production and therefore represent key elements of a suite of indicators. It was generally agreed that Instream Flow and Flow Hydrology are essentially the same for the purposes of defining indicators, and can be combined, if the combined indicator encompasses the hydrological cycle.

Comments from participants related to the selection and application of "Flow" as an indicator included the following:

- The information that should be obtained for each target stream is the percentage of mean annual flow;
- It may be possible to draw upon data from existing hydrometric stations; however, concerns were raised that the geographic coverage for hydrometric data collection may be inadequate.
- There will likely be a requirement for more hydrometric stations to be established, although in some cases staff gauges may provide sufficient data; and
- The use of surrogates in the form of "Pressure" indicators may help to reduce the number of hydrometric stations required. A "Pressure" indicator, such as Landuse Conversion, would indicate areas where changes in flows might be expected and warrant more detailed data collection through a hydrometric station.

Water Abstraction

Participants agreed that "Water Abstraction" is an important and relevant "Pressure" indicator that is related to flow hydrology. It was noted that data are collected and reported regularly for licensed "Water Abstraction" and the available database is quite good.

Sediment

Participants agreed that Sediment is one of the most fundamental indicators. It was also agreed that the utility and effectiveness of Sediment as an indicator would be enhanced by complementary data from "Pressure" indicators such as Landslides, Natural Disturbance, Road Density, Landuse Conversion, etc.

Participants contributed the following input related to Sediment:

- If data-coverage for Sediment is a problem, then it may be possible to apply the indicator at three geographic scales: Detailed level for specific areas/locations; Broadscale Level (less expensive); and perhaps a third scale such as a Watershed watershed scale;
- It was noted that, because collection of Sediment data normally involves laboratory analysis, it would likely be too expensive to apply on a large scale. Sediment is, however, an important indicator to include;
- Sediment is important at some locations and not at others. For this reason, application of Sediment as an indicator will likely have to be site specific, underlining the fact that routine application of all elements of a suite of indicators may not always be possible;
- As a strategy to make Sediment monitoring more feasible, it would be possible to identify sources of sediment and then monitor the Sediment sources. Quite a lot of work has been done on this topic. Sediment source information is needed in any case, in order to understand the origin of measured data;
- A surrogate for sediment is Turbidity, which is easy to measure but requires calibration against sediment for individual areas;
- It may be most appropriate to consider the application of Sediment as an indicator on three levels:
    - Research
    - Monitoring (Coarse)
    - Intermediate—monitor a few places routinely
- The stratification of sampling data collection effort introduced above suggests the use of sentinel streams to ground-truth the coarse level monitoring data, possibly including data gathered through remote sensing to detect degrees of change;
- It is impossible to sample all streams, so appropriate and effective sampling design is an important requirement;
- It may be possible to identify priority area through the use of related "Pressure" indicators such as landslides, road density, and natural disturbance mapping, etc.;
- It was recognized that it would likely not be possible to sample enough streams in a CU to have an adequate sample, suggesting that for indicator application, it may not be possible to adhere to the CU concept. The CU concept can; however, be applied when taking management decisions on the appropriate response to changes identified by indicators;
- In establishing stations for indicator data collection, it may be necessary to consider multiple stations within a given CU; and
- In some cases, sediment effects may not appear for two years after a "Pressure" has occurred. There are benefits to selecting indicators where it is not necessary to wait for a lag time for an effect to manifest itself.

Substrate

Substrate has generally been used as an indicator with respect to the proportion of infilling with sediment (embeddedness). Participants suggested that Substrate use as an indicator is generally not strong. Due to time constraints within the expert technical workshop, this point was not explored in great depth.

It was, however, agreed that substrate can be an effective indicator in estuaries where rocks may be put into intertidal marsh habitat as part of port or harbour/marina development.

Estuarine Wetland Area

Participants agreed that "Estuarine Wetland Area" is one of the most powerful indicators for estuaries. It was noted that estuarine ecosystems have been added to the National List of Indicators, which may provide a vehicle for obtaining monitoring data.

Area of Spawning Habitat

Participants agreed that "Area of Spawning Habitat" is an important habitat feature related to CU management. Participants did, however, agree that as an indicator, "Area of Spawning Habitat" may be overly complex, combining too much information to be workable. It was agreed that this indicator should not be included on the list at this time.

Off-channel Habitat

Participants agreed that "Off-channel Habitat" is a useful indicator. It was suggested that the specific parameter might be percentage of all off-channel habitat that is useable. It was generally recognized that this indicator would require further development before it could be implemented, because quantification of "Off-channel Habitat" over an entire CU or watershed would be a significant challenge, and the data may not be available at an appropriate level of detail.

Floodplain Encroachment

Participants agreed that "Floodplain Encroachment" is a relevant "Pressure" indicator and possibly a "State" indicator. Floodplains are being encroached upon and this does affect habitat quantity and quality, as well as access to habitat. In developing and implementing such an indicator; however, it would be important to differentiate from other related indicators such as "Off-channel Habitat" and "Estuarine Wetland Area", or it might be preferable to incorporate the important elements of "Floodplain Encroachment" into those other indicators.

Barriers to Access

Participants agreed that "Barriers to Access" represents a relatively straightforward and easily measured indicator. Data are readily available for anthropogenic barriers, such as dams and weirs, since they are generally licensed by the province and/or Authorized by DFO. In addition, data documenting existing natural barriers, such as falls, are generally available. Temporary or permanent barriers that result from natural events such as slides, earthquakes, falling trees, etc. would be more difficult to track.

Participants agreed that "Barriers to Access" can have important implications for wild Pacific salmon production and should be included in any agreed upon suite of indicators. It was noted that it will be important to distinguish between natural and anthropogenic barriers.

Large Woody Debris

Participants agreed that "Large Woody Debris" is an important indicator to include. "Large Woody Debris" is an essential component of productive wild Pacific salmon habitat. In addition, studies have shown that "Large Woody Debris" recruitment is also very important.

Collecting data on this indicator can be quite effort intensive and costly, requiring standard protocols and a high density of measurements. Detailed information is available for some areas. For practical purposes, it was agreed that monitoring this indicator may have to be based on monitoring sentinel streams, supported by broad-scale monitoring.

Benthic Macroinvertebrates

Participants generally agreed that "Benthic Macroinvertebrates" are a good indicator of habitat health and productivity. It was, however, recognized that monitoring "Benthic Macroinvertebrates" is very expensive. It was also recognized that the data obtained are highly reflective of the specific characteristics of the sampling site and it may or may not be appropriate to extrapolate beyond that site.

It was noted that "Benthic Macroinvertebrates" may be appropriate to include at the more detailed study level of a tiered system of monitoring (e.g., at the Sentinel Stream or Detailed Study levels). The Canadian Aquatic Biomonitoring Network (CABIN) is implementing "Benthic Macroinvertebrates" monitoring at a national level and may have data to contribute and/or may provide an approach to tiered study design that could be drawn upon.

Participants agreed that "Benthic Macroinvertebrates" should be kept on the list as candidate indicator; however, the acknowledged technical and cost limitations should be noted and application may not be possible at broad-scale.

Zooplankton, Phytoplankton, Chlorophyll *a*

Participants agreed that "Zooplankton, Phytoplankton, Chlorophyll *a*" are appropriate for inclusion as indicators for lake productivity, primarily with respect to sockeye CUs. Some data are being collected, although there is not complete coverage. In specifying these parameters for inclusion in a suite of indicators, it will be important to provide direction on whether and how these should be included as Indices, highlighting what is gained/lost in implementing an index approach.

Water Quality

Participants agreed that "Water Quality" is an important and relevant indicator, particularly in relation to municipalities and industrial sites/operations. Data from point source inputs (e.g., municipalities, mines, abandoned mines, pulp mills, etc.) are generally collected and maintained in provincial and/or federal databases. These pollutant inputs can have an effect on wild Pacific salmon CU production. Water quality data are also available from programs to monitor municipal water supplies and waters used for recreational purposes.

In selecting "Water Quality" as an indicator, it will be necessary to specify whether this is to be tracked as individual parameters or as an index. If "Water Quality" is to be tracked as an index, then the composition of that index will need to be defined. It is possible that an index would be tracked at the broad-scale level, while specific parameters would be tracked at the level of Sentinel Stream and/or Detailed Study.

Chemical Contaminants

Participants generally recognized that point source "Chemical Contaminants" inputs could have some degree of relevance to production for a wild Pacific salmon CU. It was noted, however, that developing a "Chemical Contaminants" indicator and tracking the indicator could become quite complex and costly.

In the interests of moving the indicator initiative forward in the most timely and cost effective manner, it was agreed that the inclusion of "Chemical Contaminants" should be deferred until experience is gained in developing and implementing more straightforward indicators.

In the course of this discussion, participants agreed that, in order to foster successful adoption and implementation of a habitat indicator program for wild Pacific salmon, it would likely be preferable to start with a relatively short list of approximately five (5) straightforward, practical indicators and move beyond that list as experience is gained. In agreeing upon this approach, it was recognized that hotspots for "Chemical Contaminants" with the potential to affect production would likely be identified, tracked and addressed through other provincial, territorial, federal and municipal programs.

Invasive Species

Participants noted that the presence of invasive species (e.g., Bass in the Fraser River, invasive aquatic plants) can have important effects on salmon production. This was raised as a relevant consideration and perhaps for inclusion as an indicator at a future date.

6.0 Recommended Next Steps

Overall, participants generally agreed that the Main Report provided an effective overview of the current state of indicator development and implementation for wild Pacific salmon habitat. Participants agreed that there will always be additional information sources and/or references to cite; however, it is unlikely that the overall conclusions would change substantively. Those conclusions being that:

- There is a great deal of commonality in the indicators identified through most initiatives documented in the literature;
- There is little to be gained by continuing to review indicator development processes. It is more productive to begin "doing";
- Most initiatives have faltered between the stage of indicator identification and effective medium to long term implementation;
- "Pressure" indicators should be used because data generally appear to be more readily available than for other types of indicators and they may be useful to help explain changes in "State" indicators; and
- The preferred approach is to work collaboratively with other levels of government, First Nations, and stakeholders, in partnership arrangements where possible, to analyse and rationalise indicators for selection and to implement indicators on an incremental basis using an adaptive management approach.

Participants agreed that steps can and should be taken to move the indicator selection initiative forward. However, participants also recognized that, as indicated by the Main Report, the step between indicator identification and implementation is the critical juncture where habitat indicator initiatives have faltered. In order to minimize the potential for this happening, participants agreed that a strategic approach to confirmation of wild Pacific salmon habitat indicators should be pursued, in order build organizational and stakeholder receptiveness and support. This would facilitate adoption of the recommended indicators as well as the development and implementation of programs and partnerships required to support them, over the long term. Key steps that could be taken are outlined below.

Recommended Initiative #1. Complete Interdisciplinary Indicator Feasibility Confirmation

A suite of candidate indicators was identified in the Main Report and a preliminary analysis was developed. The results are found in Appendix 1 to the Main Report. The information and analysis for each indicator was drawn from the literature and the knowledge, experience and judgment of the consulting team. This analysis was intended to be a first cut.

Participants agreed that an analysis should be completed for each indicator on the shortlist against identified criteria. The analysis could be done in a matrix, or using the tables presented in Appendix 1 to the Main Report. Participants also recommended that each indicator be examined by a specialist in a discipline/interest relevant to the indicator and the potential inclusion of data from related data-collection programs (for example, participants identified for consideration: Environment Canada CABIN program, the joint provincial/Nature Conservancy of Canada Ecological Aquatic Units of BC program and Okanagan Nation Alliance EMAP data collection activities). This led to the conclusion that the indicator feasibility confirmation analysis should be completed by a group, possibly including stakeholders. Stakeholder inclusion would be particularly relevant for those indicators where it is expected that partnership arrangements would be required in order to ensure successful indicator implementation.

For those indicators that are recommended for adoption, an implementation action plan should be developed by the multi-disciplinary team charged with completing the indicator feasibility confirmation analysis.

Recommended Initiative #2. Provincial Snapshot

As a complement to the interdisciplinary analysis, participants agreed that it would be useful to prepare a "Provincial Snapshot" for wild Pacific salmon habitat, using indicators in Appendix 1 to the Main Report, to the extent possible. Participants felt this exercise would provide a real test as to what can be achieved with available data from existing programs to track habitat indicators in CUs. Some databases were identified that could be used as a starting point for this "Provincial Snapshot", including: the British Columbia Watersheds Atlas; the Fisheries Information Summary System; and the British Columbia Land and Resource Data Warehouse.

Results from this test would help to inform the interdisciplinary indicator feasibility confirmation analysis discussed above. It was recognized that any initiative to prepare a "Provincial Snapshot" would have to be designed to effectively gather project management and effectiveness information in order to inform the indicator selection process.

Recommended Initiative #3. Pilot Implementation Watersheds

Participants agreed that implementation of identified indicators through a series of Pilot Watersheds would serve to test: availability of data; inter-comparability of data; viability of various partnership approaches; and utility of the findings in terms of informing CU management decisions. Participants also agreed that this would help to identify levels of effort, professional expertise and costs for implementation on a wider scale. It was recognized that any initiative to implement indicators on Pilot Watersheds would have to be designed to effectively gather this project management and effectiveness information in order to derive the intended program management benefits from a pilot scale exercise. The experience from implementing a pilot scale indicator test for the Snohomish River watershed (Ward 1999) was influential in achieving participant consensus on this point. While Ward (1999) was very instructive in terms of challenges and resource requirements, it was considered that the specific findings could not be directly extrapolated to B.C., because jurisdictions, data sources, agencies, etc. are so different.

Participants considered that a pilot program to implement indicators on up to approximately 15 watersheds would be appropriate. There would be a need to test indicator application in various environmental conditions, topographies and CUs, with a variety of "Pressures", and to ensure that all life stages of all wild Pacific salmon species are addressed. Participants agreed that the selection of each Pilot Watershed would need to be effectively rationalized against these considerations and other relevant considerations that may emerge.

Adaptive Management

Establishing a suite of habitat indicators for wild Pacific salmon habitat that will be implemented effectively and over an appropriate timeframe is a significant challenge. The approach to indicator identification and staged implementation outlined above was considered reasonable given past experience and the enormity of the challenge. If implemented effectively, with proper tracking of objectives, roles and responsibilities, resources, outcomes, and lessons learned, etc., this approach will provide a solid basis for adaptive management. There was strong agreement among workshop participants in terms of the soundness of the approach and the advantages of beginning early, on a smaller scale, and adapting and growing as experience is gained among the relevant parties.

Communications

Participants agreed that each of the above steps provides a reasonable vehicle to accomplish concrete progress toward implementation of the habitat tracking aspects of the Wild Pacific Salmon Policy.

This strategy would provide an excellent, solidly rationalized basis for communicating progress, working with First Nations, demonstrating the engagement of partners and working positively with stakeholders. It would provide an effective vehicle for communicating successes, and a defensible basis for communicating the reasons for any setbacks that may arise and developing strategies to address them.

References

Ward, W. J. 1999. Pacific Northwest Salmon Habitat Indicators—Pilot Project, Snohomish River basin. Prepared for the Washington State Department of Ecology.

Workshop Report Appendices

Appendix 1. Expert Technical Workshop Agenda

Wild Pacific Salmon Habitat Indicators
Proposed Expert Technical Workshop Agenda
November 17, 2005

Morris J. Wosk Centre for Dialogue
Executive Meeting Room 470
Simon Fraser University Vancouver
580 West Hastings Street, Vancouver, B.C.

08:30–09:00	Introduction—G. Ennis & G. Packman ▪ Workshop Purpose ▪ Agenda Review ▪ Participant Introductions ▪ Project objective and initial thoughts on how this workshop can advance the agenda
09:00–10:00	Review of Information Base—G. Packman & M. Winsby ▪ Review of Workshop Background Document
10:00–10:15	▪ What does the Background Document tell us, on a macro level? ▪ How should the various levels of application be taken into account? (i.e., Province, Watershed, Sub-watershed, Lake, Stream, River, Estuary)
10:15–10:30	**Break**

10:30–10:45	Wild Pacific Salmon Policy Habitat Strategy: Status/Needs-DFO
	▪ Update/Discussion (WSP Strategy 1, Action Step 1.1): Status of Conservation Unit identification?
	    ▪ Does the background information appropriately address the Wild Pacific Salmon Policy and Pacific salmon species information?
	▪ Update/Discussion (WSP Strategy 2, Action Step 2.1): Documentation of habitat characteristics in Conservation Units?
	    ▪ Does the background information include the key information related to wild Pacific salmon Habitat Indicators?

10:45–11:30	Roundtable on Habitat Indicators for wild Pacific salmon
	▪ What is the purpose of Habitat Indicators?
	▪ What types of Habitat Indicators are we looking for?
	    ▪ Pressure?
	    ▪ State?
	    ▪ Impact?
	    ▪ Response?
	▪ What approach(es) should be applied to selecting indicators?
	▪ Past Experience
	    ▪ Progress Made?
	    ▪ Barriers to building concensus on Habitat Indicators?
	    ▪ Barriers to implementation?

11:30–12:00	▪ Have the key indicator identification studies been identified in the Background Document?
	    ▪ Are any key studies missing?
	▪ Have the key information sources been identified?
	    ▪ Are any key sources missing?

12:00–13:00	**Lunch**

13:00–13:30	Habitat Indicators: Selection and Implementation Strategy
	▪ What are the characteristics that wild Pacific salmon Habitat Indicators should reflect?
	    ▪ Review of characteristics identified by others
	    ▪ Any to add / delete?
	    ▪ Considerations?

13:30–14:00	▪ Data to Support Indicators ▪ Roundtable discussion on data needs and sources

14:00–14:45	▪ What process should be used for identifying and implementing wild Pacific salmon Habitat Indicators?
	▪ How would available resources impact the decision on process. What would be the approach with a budget of $50k, $100k and $500k
	    ▪ Identify indicators and implement?
	    ▪ Iterative approach?
	    ▪ Build on opportunities?
	    ▪ Pilot Conservation Units?

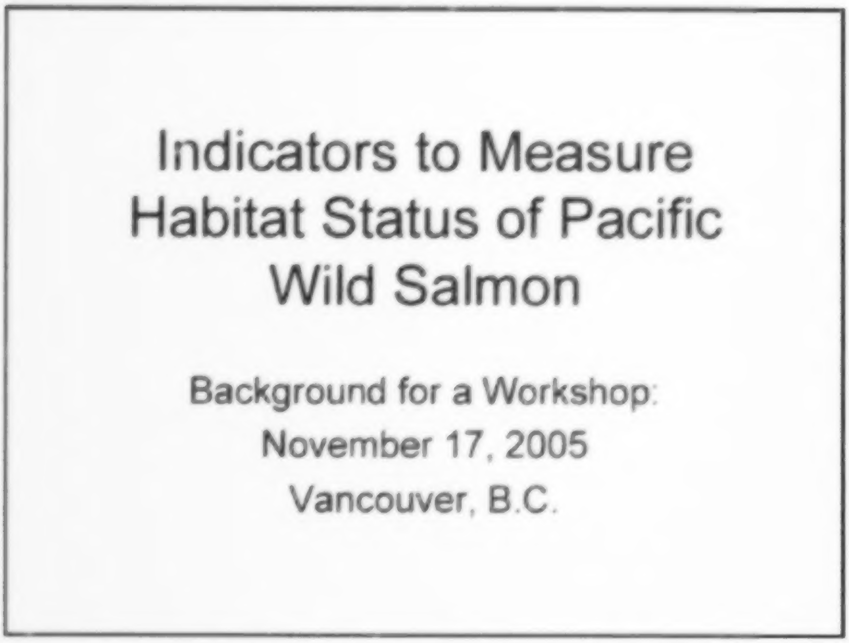
14:45–15:00	**Break**
15:00–16:00	Formulation of Recommendations How do we move forward to ensure successful indicator development / implementation?
16:00–16:30	Next Steps ▪ Completing the report ▪ Indicator development, Pilot testing, and Refinement

Appendix 2. Expert Technical Workshop Participants

Pacific Fisheries Resource Conservation Council	
Paul LeBlond	Chair
Mark Angelo	Vice-Chair
Jeff Marliave	Council Member
Gordon Ennis	Managing Director
Glen Packman	Consultant, G.A. Packman & Associates
Malcolm Winsby	Consultant, Winsby Environmental Services
Fisheries and Oceans Canada	
Karen Calla	Senior Program Review Biologist, Oceans/Watershed Planning and Restoration
Blair Holtby	Head, Salmon Section
Brad Mason	Habitat Inventory Coordinator, Geographical Information Systems & Habitat Inventory
Jim Irvine	Research Scientist, Conservation Biology Section
Brian Riddell	Senior Scientist, Pacific Biological Station
Heather Stalberg	Senior Habitat Management Biologist, Oceans, Habitat and Enhancement Branch
Gary Taccogna	Area Chief, Oceans and Community Stewardship
Neil Schubert	Area Chief, Stock Assessment
Jeremy Hume	Research Biologist, Cultus Lake Salmon Research Laboratory
Mike Bradford	Head, Freshwater Rearing, Cooperative Resource Management Institute
Environment Canada	
Risa Smith	Senior Science Advisor, Biodiversity Convention Office, Environment Canada Pacific and Yukon Region
BC Ministry of Forests and Range	
Dan Hogan	Research Scientist, Geomorphology, Fish-Forestry Interaction and Watershed Research
BC Ministry of Environment	
Art Tautz	Manager, Research and Development, Ecosystem Branch
David Tesch	Head, Fisheries Business Programs, Ecosystem Information Section

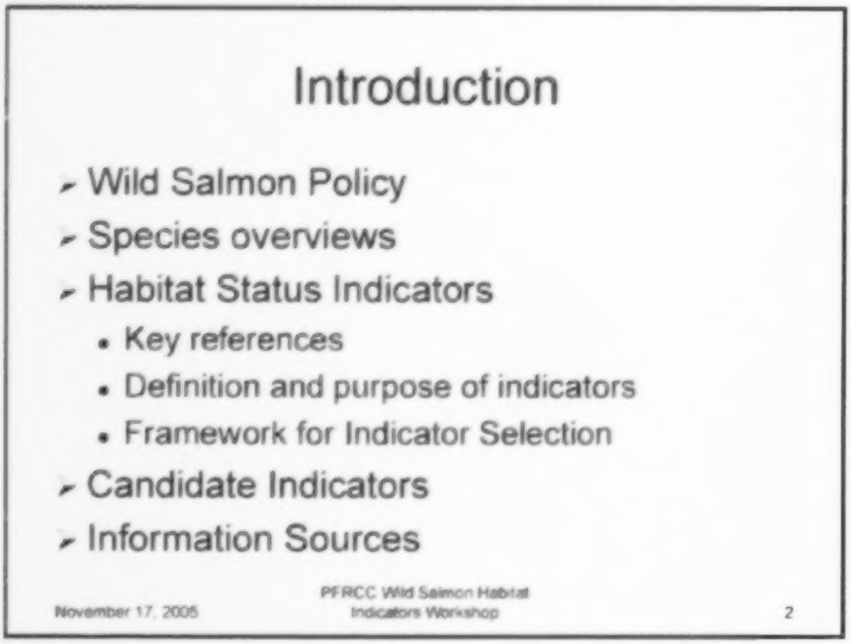
BC Ministry of Agriculture and Lands	
Malcolm Gray	Team Leader, Remote Sensing Services, Integrated Land Management Bureau
Skeena Fisheries Commission	
Allen Gottesfeld	Head Scientist
Kenny Rabnett	Senior Fisheries Technician
Okanagan Nation Alliance	
Howie Wright	Senior Fisheries Biologist
Non-governmental Organizations and Consultants	
Patrick Slaney	P Slaney Aquatic Science Ltd
Mark Nelitz	ESSA Technologies Ltd
Jeffrey Young	David Suzuki Foundation
Kristy Ciruna	Coordinator of Conservation Programs, Nature Conservancy of Canada
Margaret Branton	Graduate Student, Faculty of Forestry, University of British Columbia

Appendix 3. Workshop Presentations



Indicators to Measure Habitat Status of Pacific Wild Salmon

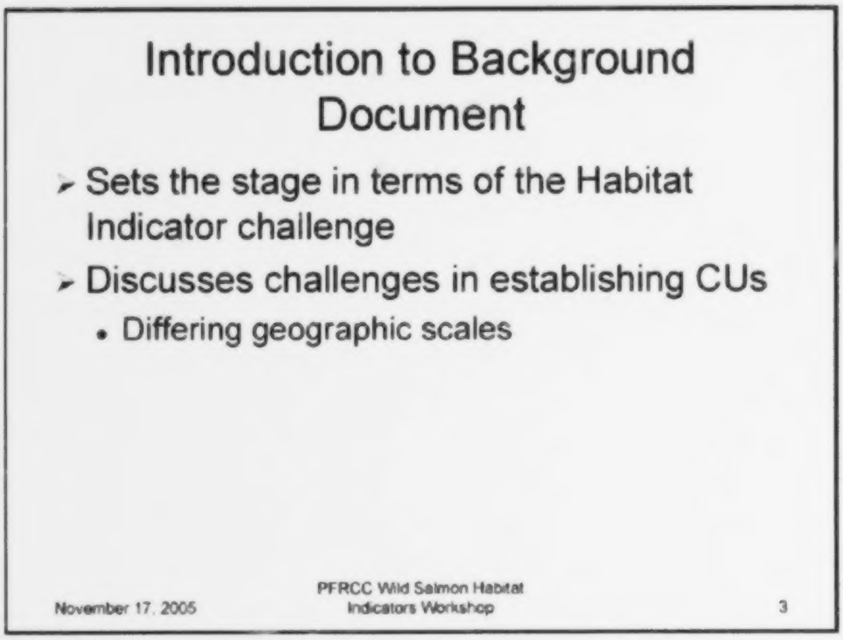
Background for a Workshop:
November 17, 2005
Vancouver, B.C.



Introduction

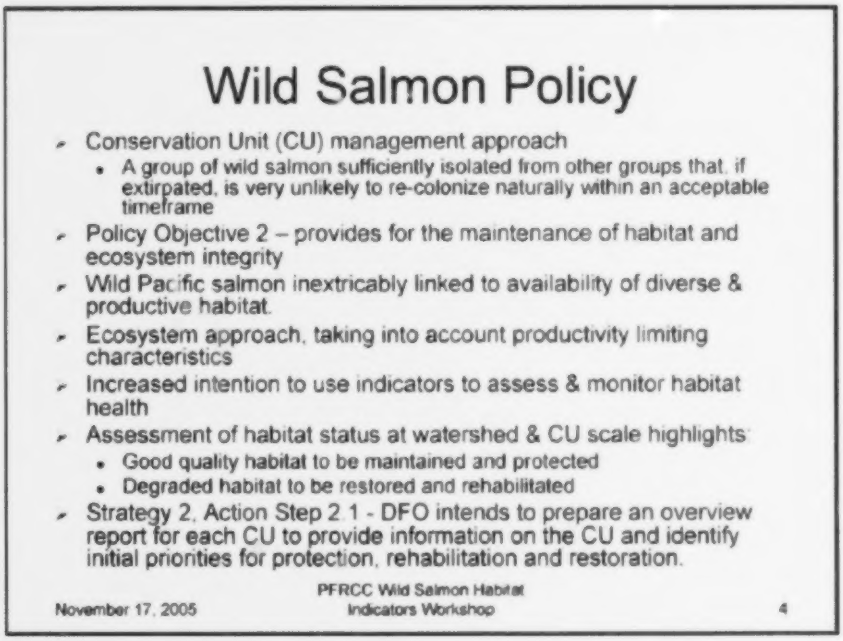
- Wild Salmon Policy
- Species overviews
- Habitat Status Indicators
  - Key references
  - Definition and purpose of indicators
  - Framework for Indicator Selection
- Candidate Indicators
- Information Sources

November 17, 2005 PFRCC Wild Salmon Habitat Indicators Workshop 2



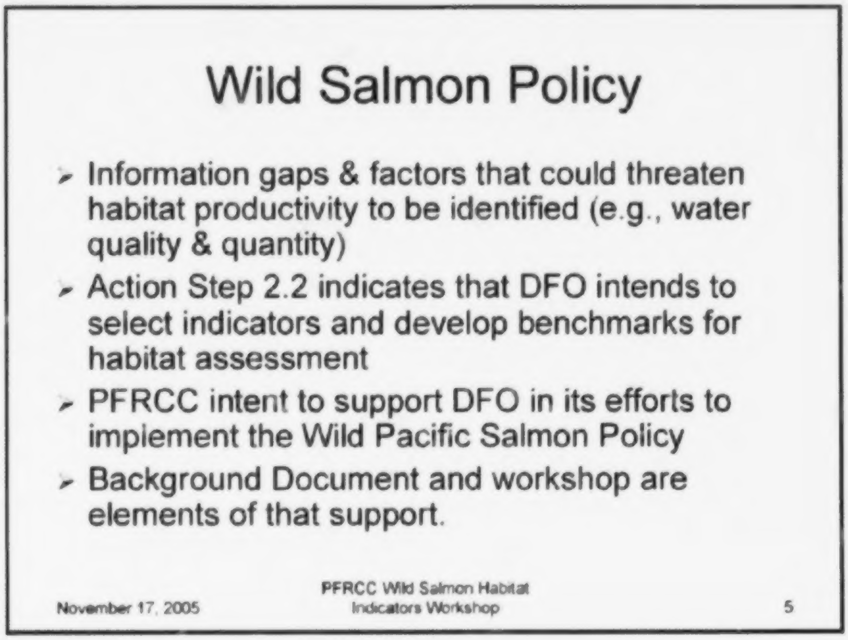
Introduction to Background Document

- Sets the stage in terms of the Habitat Indicator challenge
- Discusses challenges in establishing CUs
  - Differing geographic scales



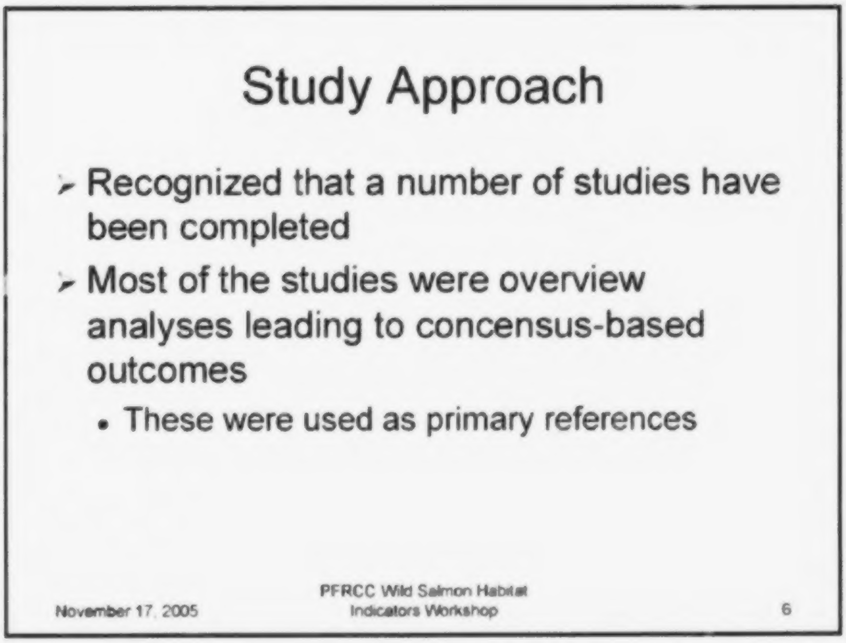
Wild Salmon Policy

- Conservation Unit (CU) management approach
  - A group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to re-colonize naturally within an acceptable timeframe
- Policy Objective 2 – provides for the maintenance of habitat and ecosystem integrity
- Wild Pacific salmon inextricably linked to availability of diverse & productive habitat.
- Ecosystem approach, taking into account productivity limiting characteristics
- Increased intention to use indicators to assess & monitor habitat health
- Assessment of habitat status at watershed & CU scale highlights:
  - Good quality habitat to be maintained and protected
  - Degraded habitat to be restored and rehabilitated
- Strategy 2, Action Step 2.1 - DFO intends to prepare an overview report for each CU to provide information on the CU and identify initial priorities for protection, rehabilitation and restoration.



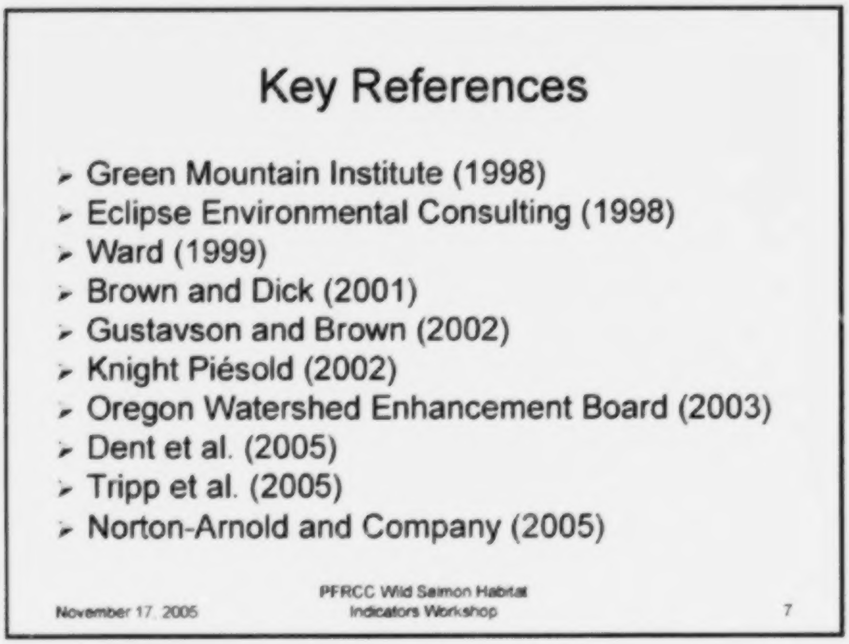
Wild Salmon Policy

- Information gaps & factors that could threaten habitat productivity to be identified (e.g., water quality & quantity)
- Action Step 2.2 indicates that DFO intends to select indicators and develop benchmarks for habitat assessment
- PFRCC intent to support DFO in its efforts to implement the Wild Pacific Salmon Policy
- Background Document and workshop are elements of that support.



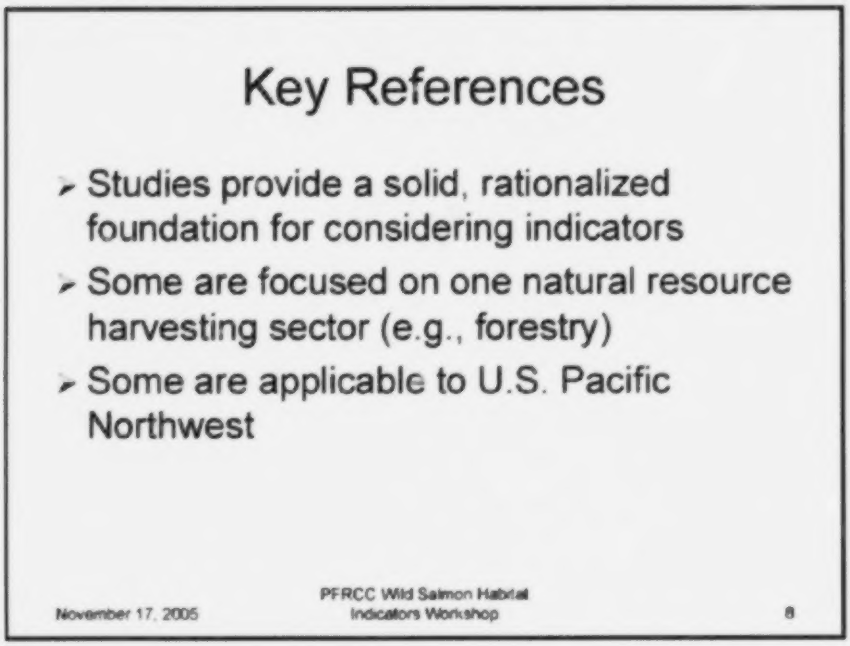
Study Approach

- Recognized that a number of studies have been completed
- Most of the studies were overview analyses leading to concensus-based outcomes
  - These were used as primary references



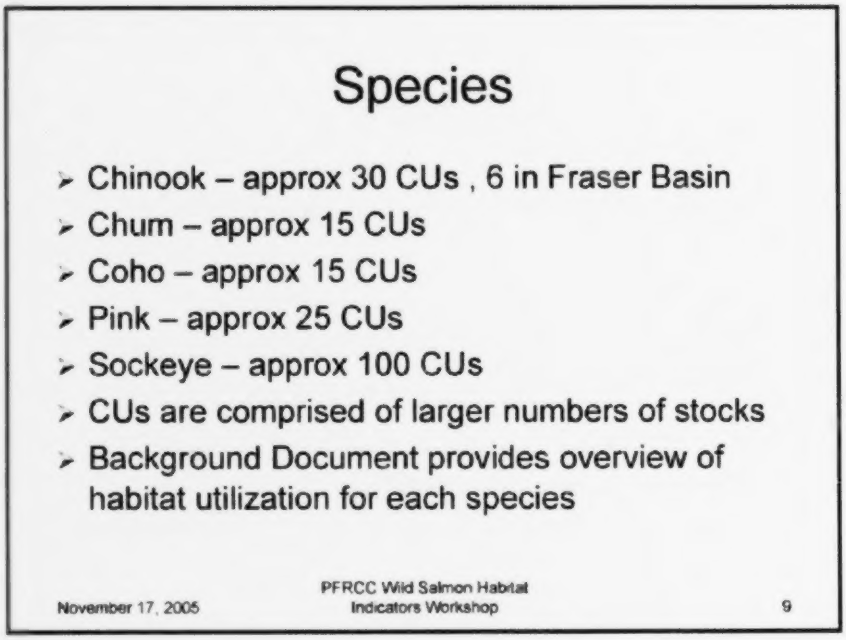
Key References

- Green Mountain Institute (1998)
- Eclipse Environmental Consulting (1998)
- Ward (1999)
- Brown and Dick (2001)
- Gustavson and Brown (2002)
- Knight Piésold (2002)
- Oregon Watershed Enhancement Board (2003)
- Dent et al. (2005)
- Tripp et al. (2005)
- Norton-Arnold and Company (2005)



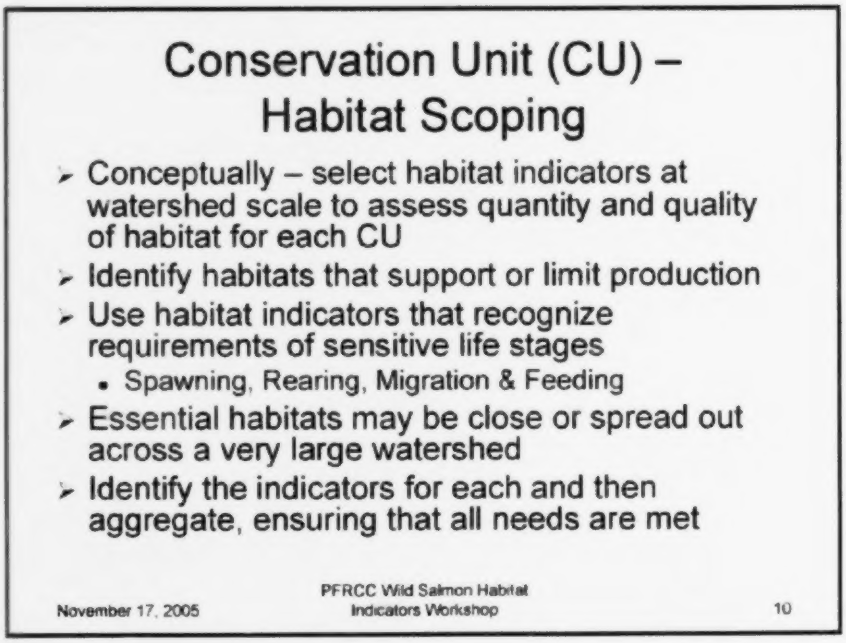
Key References

- Studies provide a solid, rationalized foundation for considering indicators
- Some are focused on one natural resource harvesting sector (e.g., forestry)
- Some are applicable to U.S. Pacific Northwest



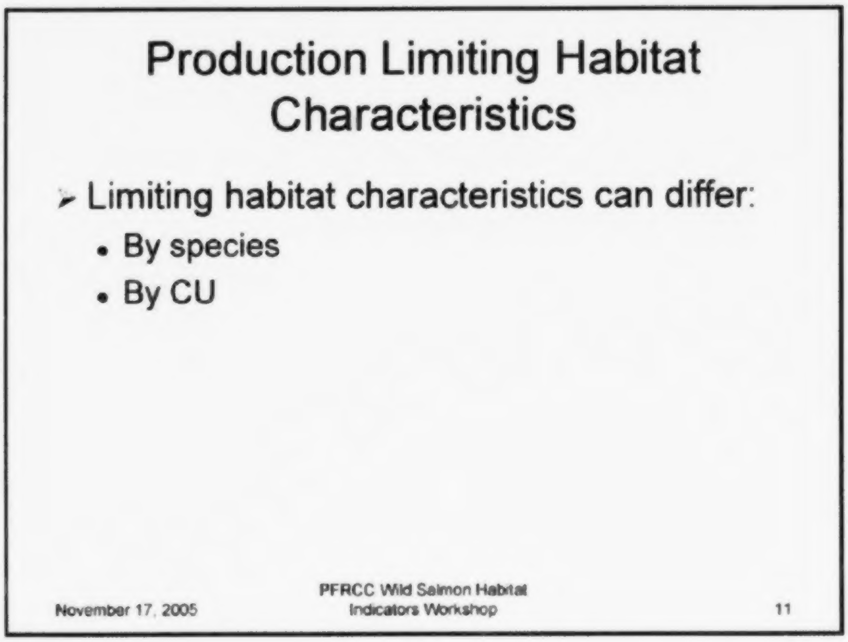
Species

- Chinook – approx 30 CUs , 6 in Fraser Basin
- Chum – approx 15 CUs
- Coho – approx 15 CUs
- Pink – approx 25 CUs
- Sockeye – approx 100 CUs
- CUs are comprised of larger numbers of stocks
- Background Document provides overview of habitat utilization for each species



Conservation Unit (CU) – Habitat Scoping

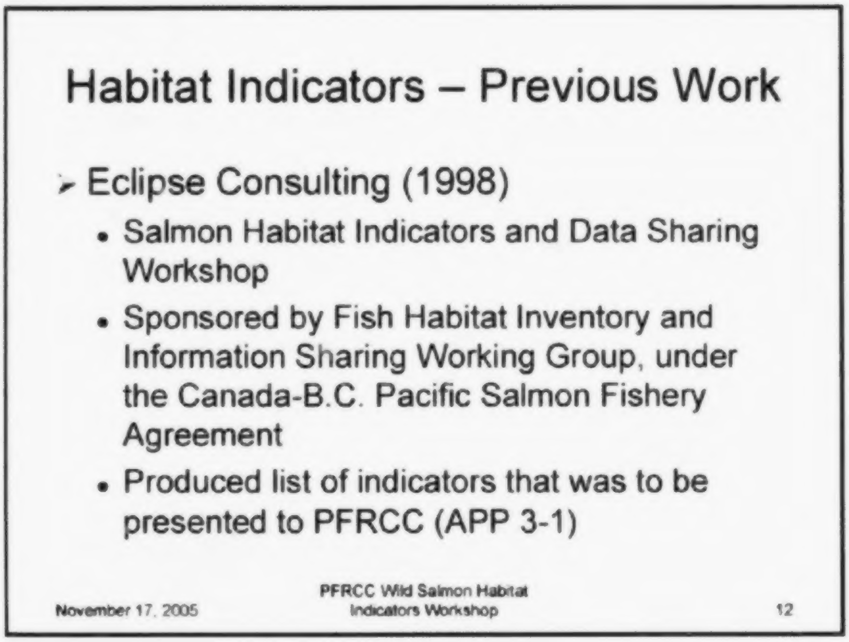
- Conceptually – select habitat indicators at watershed scale to assess quantity and quality of habitat for each CU
- Identify habitats that support or limit production
- Use habitat indicators that recognize requirements of sensitive life stages
  - Spawning, Rearing, Migration & Feeding
- Essential habitats may be close or spread out across a very large watershed
- Identify the indicators for each and then aggregate, ensuring that all needs are met



Production Limiting Habitat Characteristics

- Limiting habitat characteristics can differ:
  - By species
  - By CU

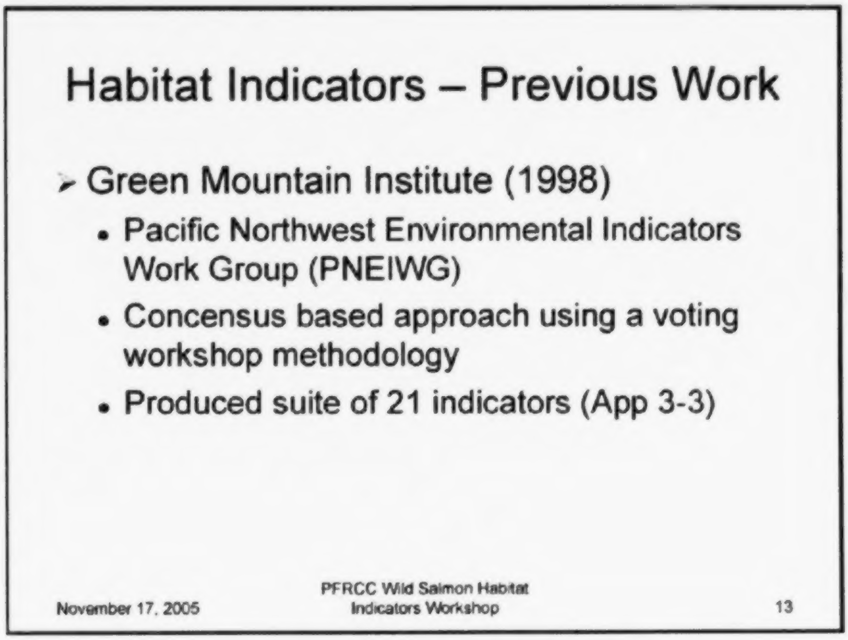
November 17, 2005
PFRCC Wild Salmon Habitat Indicators Workshop
11



Habitat Indicators – Previous Work

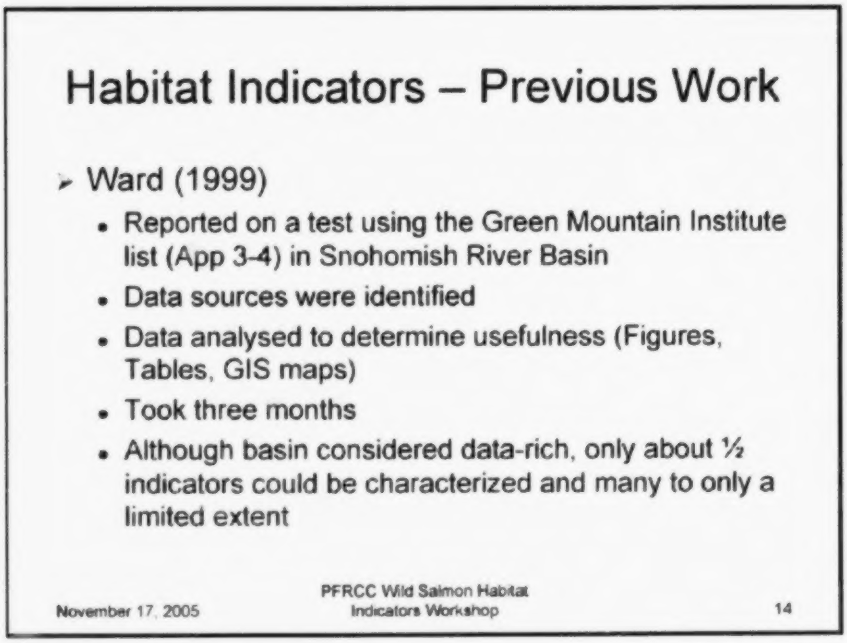
- Eclipse Consulting (1998)
  - Salmon Habitat Indicators and Data Sharing Workshop
  - Sponsored by Fish Habitat Inventory and Information Sharing Working Group, under the Canada-B.C. Pacific Salmon Fishery Agreement
  - Produced list of indicators that was to be presented to PFRCC (APP 3-1)

November 17, 2005
PFRCC Wild Salmon Habitat Indicators Workshop
12



Habitat Indicators – Previous Work

- Green Mountain Institute (1998)
  - Pacific Northwest Environmental Indicators Work Group (PNEIWG)
  - Concensus based approach using a voting workshop methodology
  - Produced suite of 21 indicators (App 3-3)



Habitat Indicators – Previous Work

- Ward (1999)
  - Reported on a test using the Green Mountain Institute list (App 3-4) in Snohomish River Basin
  - Data sources were identified
  - Data analysed to determine usefulness (Figures, Tables, GIS maps)
  - Took three months
  - Although basin considered data-rich, only about ½ indicators could be characterized and many to only a limited extent

Habitat Indicators – Previous Work

- Brown and Dick (2001)
- Gustavson and Brown (2002) (App 3-4)
- Knight Piésold (2002) (App 3-5)
- Tripp et al. (2005) (App 3-6)
- Province of B.C. initiative
- Valuable overview reports that examined approaches to development and application of indicators, primarily relevant to stream habitat and the forest sector
- Indicators proposed & rationalized

Habitat Indicators – Previous Work

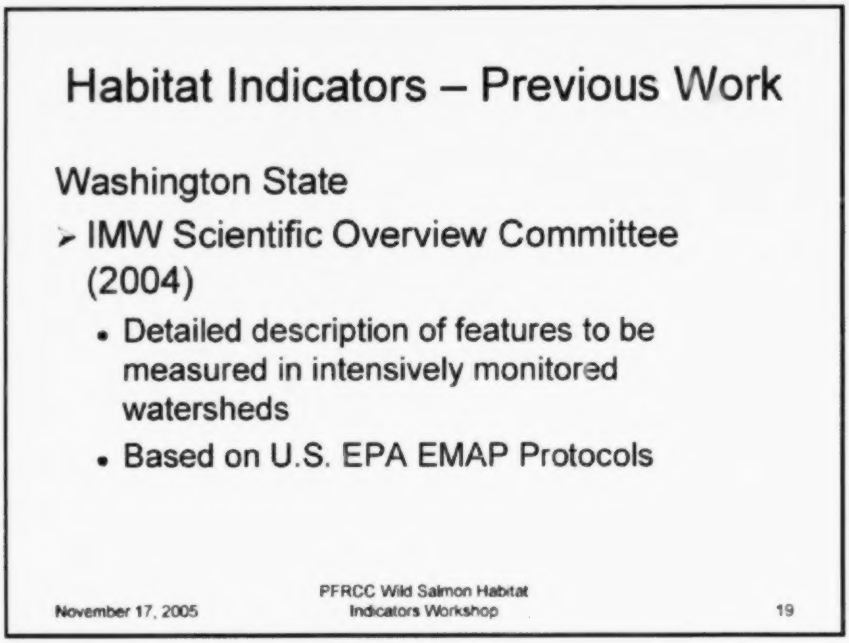
- Norton –Arnold & Company (2005) (App 3-5)
  - Policy Forum in support of the Wild Pacific Salmon Policy
  - Proposed properties of indicators
  - Proposed a list of candidate indicators

Habitat Indicators – Previous Work

- Bauer and Ralph (1999)
    - Useful aquatic habitat indicators based on existing monitoring parameters used by state and federal agencies and indicators under *Endangered Species Act*
- U.S. EPA - Environmental Monitoring and Assessment Program, Western Pilot Study
    - Studies completed using EMAP protocols
- Columbia River Federal Caucus
    - Indicators related to *Endangered Species Act*

Habitat Indicators – Previous Work

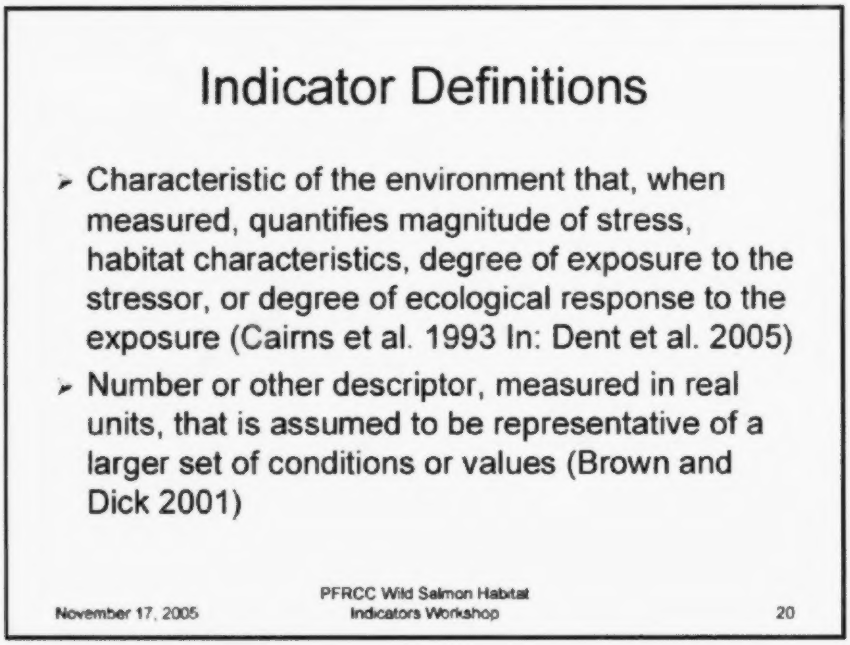
- Oregon Watershed Enhancement Board (2003)
- Dent et al. (2005)
    - If process to establish indicators bridges gap between scientific, social, and political stakeholders, outcome more likely to be successful
    - Identified a list of indicators



Habitat Indicators – Previous Work

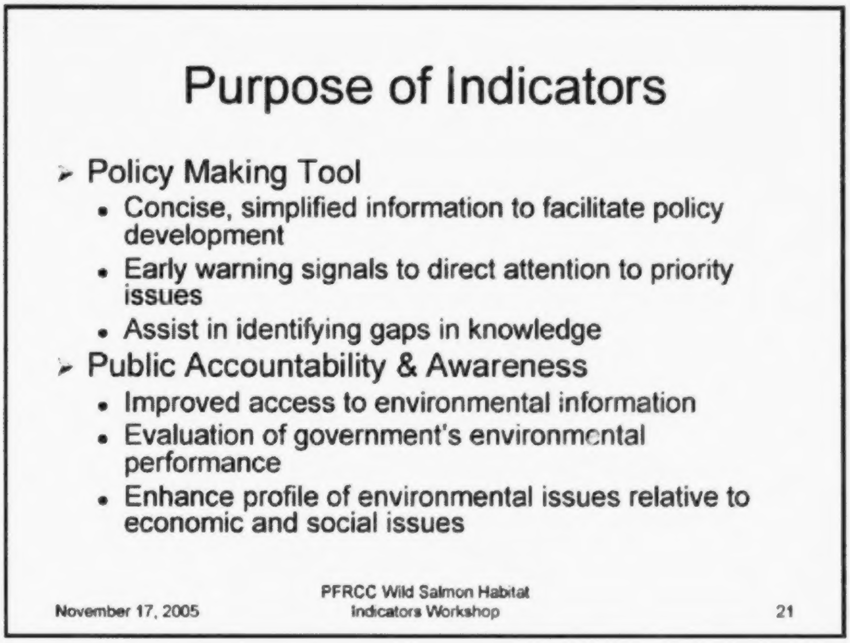
Washington State

- IMW Scientific Overview Committee (2004)
  - Detailed description of features to be measured in intensively monitored watersheds
  - Based on U.S. EPA EMAP Protocols



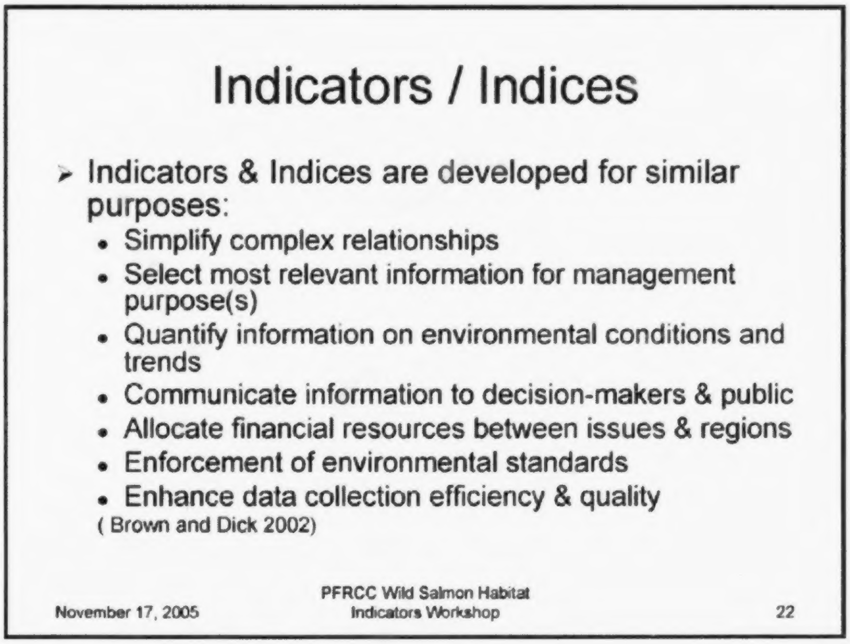
Indicator Definitions

- Characteristic of the environment that, when measured, quantifies magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure (Cairns et al. 1993 In: Dent et al. 2005)
- Number or other descriptor, measured in real units, that is assumed to be representative of a larger set of conditions or values (Brown and Dick 2001)



Purpose of Indicators

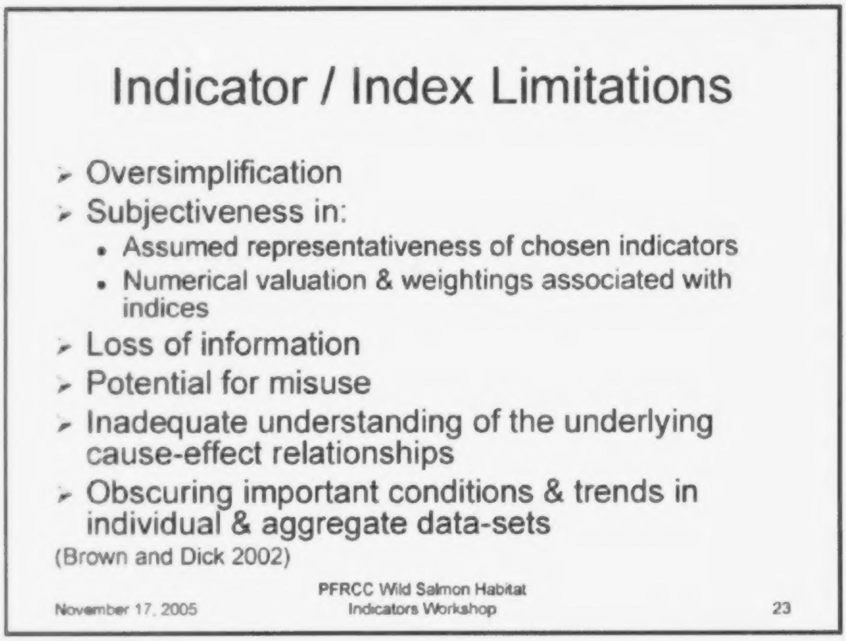
- Policy Making Tool
  - Concise, simplified information to facilitate policy development
  - Early warning signals to direct attention to priority issues
  - Assist in identifying gaps in knowledge
- Public Accountability & Awareness
  - Improved access to environmental information
  - Evaluation of government's environmental performance
  - Enhance profile of environmental issues relative to economic and social issues



Indicators / Indices

- Indicators & Indices are developed for similar purposes:
  - Simplify complex relationships
  - Select most relevant information for management purpose(s)
  - Quantify information on environmental conditions and trends
  - Communicate information to decision-makers & public
  - Allocate financial resources between issues & regions
  - Enforcement of environmental standards
  - Enhance data collection efficiency & quality

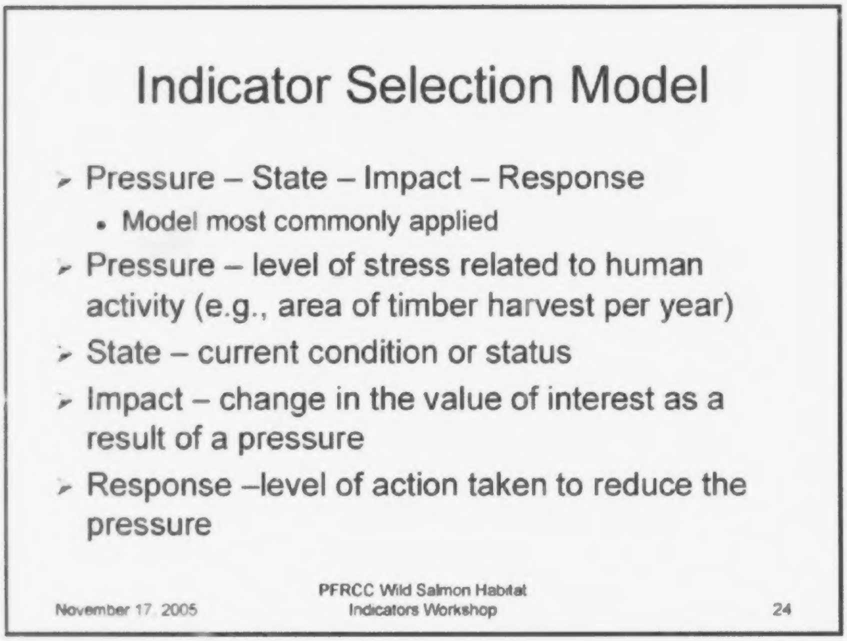
(Brown and Dick 2002)



Indicator / Index Limitations

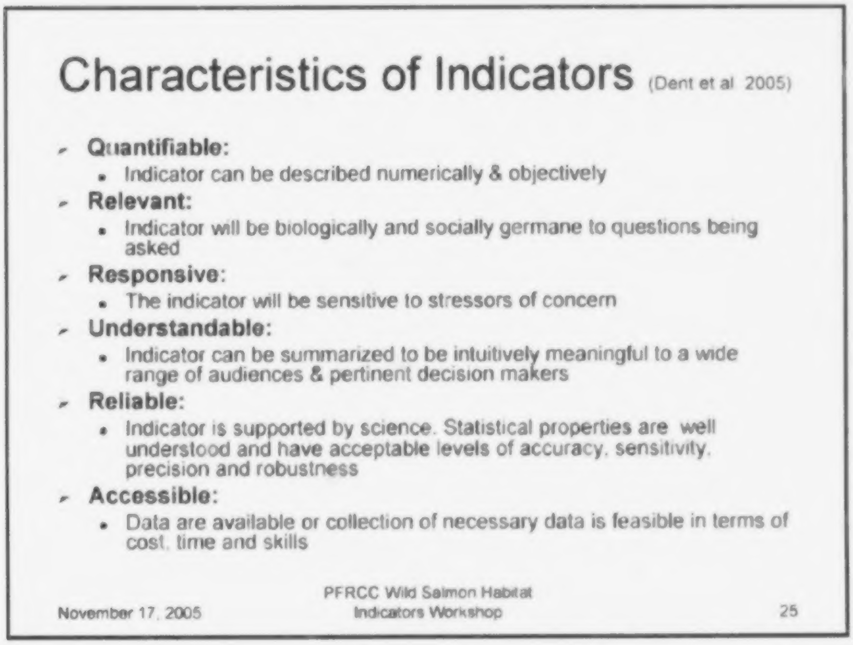
- Oversimplification
- Subjectiveness in:
  - Assumed representativeness of chosen indicators
  - Numerical valuation & weightings associated with indices
- Loss of information
- Potential for misuse
- Inadequate understanding of the underlying cause-effect relationships
- Obscuring important conditions & trends in individual & aggregate data-sets

(Brown and Dick 2002)



Indicator Selection Model

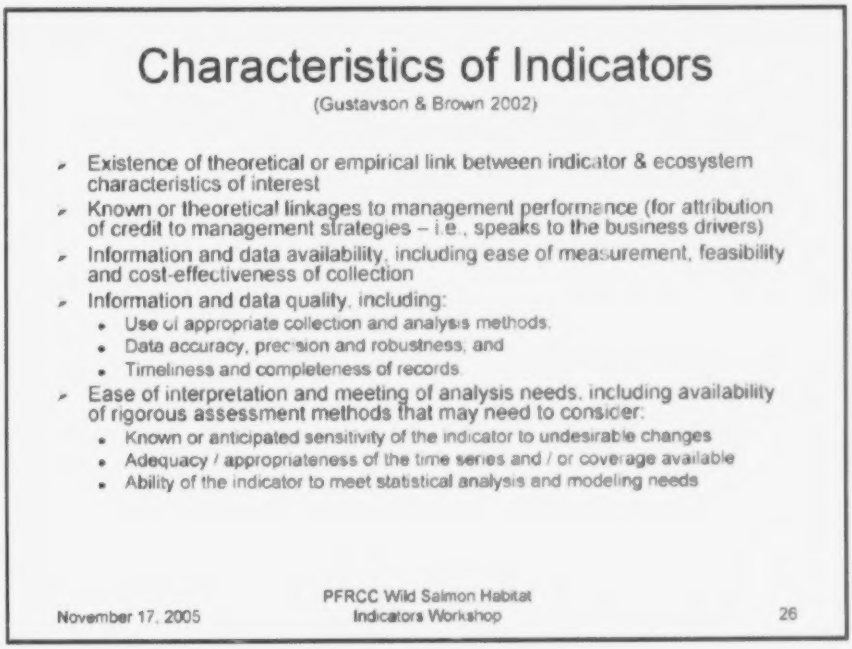
- Pressure – State – Impact – Response
  - Model most commonly applied
- Pressure – level of stress related to human activity (e.g., area of timber harvest per year)
- State – current condition or status
- Impact – change in the value of interest as a result of a pressure
- Response –level of action taken to reduce the pressure



Characteristics of Indicators (Dent et al. 2005)

- **Quantifiable:**
  - Indicator can be described numerically & objectively
- **Relevant:**
  - Indicator will be biologically and socially germane to questions being asked
- **Responsive:**
  - The indicator will be sensitive to stressors of concern
- **Understandable:**
  - Indicator can be summarized to be intuitively meaningful to a wide range of audiences & pertinent decision makers
- **Reliable:**
  - Indicator is supported by science. Statistical properties are well understood and have acceptable levels of accuracy, sensitivity, precision and robustness
- **Accessible:**
  - Data are available or collection of necessary data is feasible in terms of cost, time and skills

November 17, 2005 | PFRCC Wild Salmon Habitat Indicators Workshop | 25

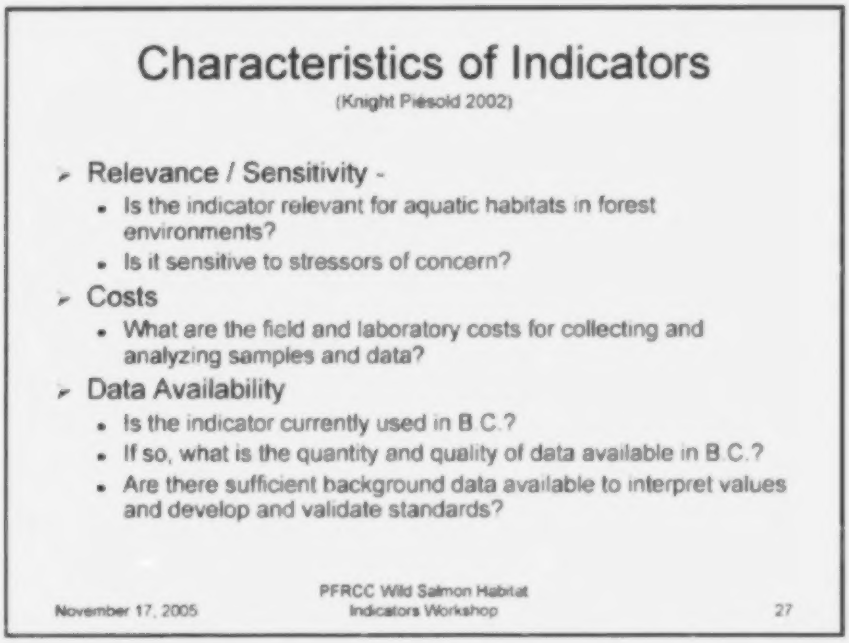


Characteristics of Indicators

(Gustavson & Brown 2002)

- Existence of theoretical or empirical link between indicator & ecosystem characteristics of interest
- Known or theoretical linkages to management performance (for attribution of credit to management strategies – i.e., speaks to the business drivers)
- Information and data availability, including ease of measurement, feasibility and cost-effectiveness of collection
- Information and data quality, including:
  - Use of appropriate collection and analysis methods,
  - Data accuracy, precision and robustness; and
  - Timeliness and completeness of records.
- Ease of interpretation and meeting of analysis needs, including availability of rigorous assessment methods that may need to consider:
  - Known or anticipated sensitivity of the indicator to undesirable changes
  - Adequacy / appropriateness of the time series and / or coverage available
  - Ability of the indicator to meet statistical analysis and modeling needs

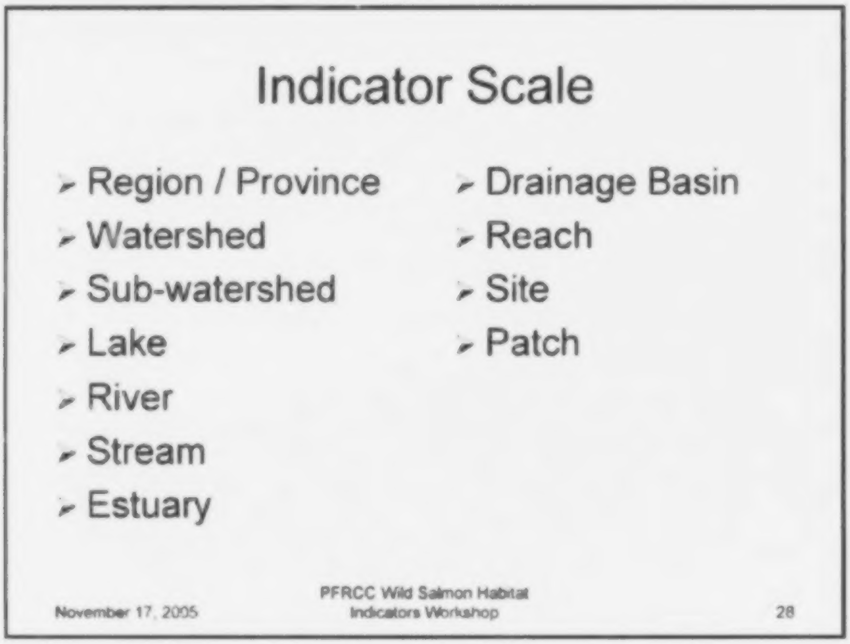
November 17, 2005 | PFRCC Wild Salmon Habitat Indicators Workshop | 26



Characteristics of Indicators

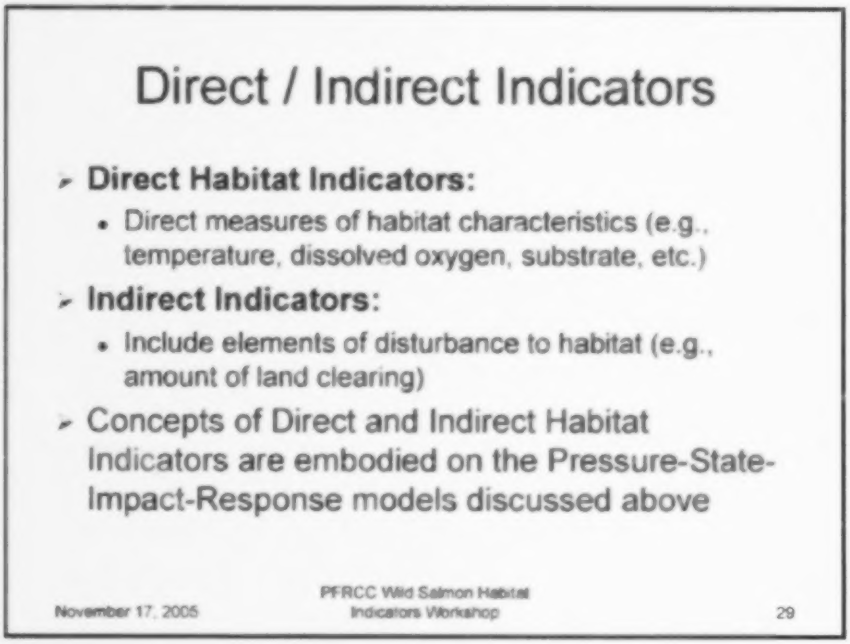
(Knight Piésold 2002)

- Relevance / Sensitivity -
  - Is the indicator relevant for aquatic habitats in forest environments?
  - Is it sensitive to stressors of concern?
- Costs
  - What are the field and laboratory costs for collecting and analyzing samples and data?
- Data Availability
  - Is the indicator currently used in B.C.?
  - If so, what is the quantity and quality of data available in B.C.?
  - Are there sufficient background data available to interpret values and develop and validate standards?



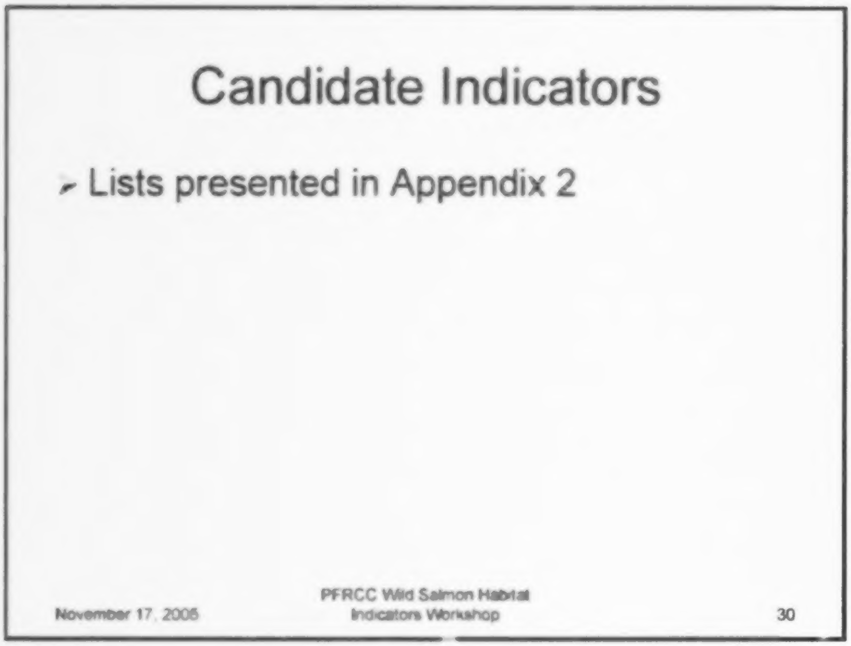
Indicator Scale

- Region / Province
- Watershed
- Sub-watershed
- Lake
- River
- Stream
- Estuary
- Drainage Basin
- Reach
- Site
- Patch



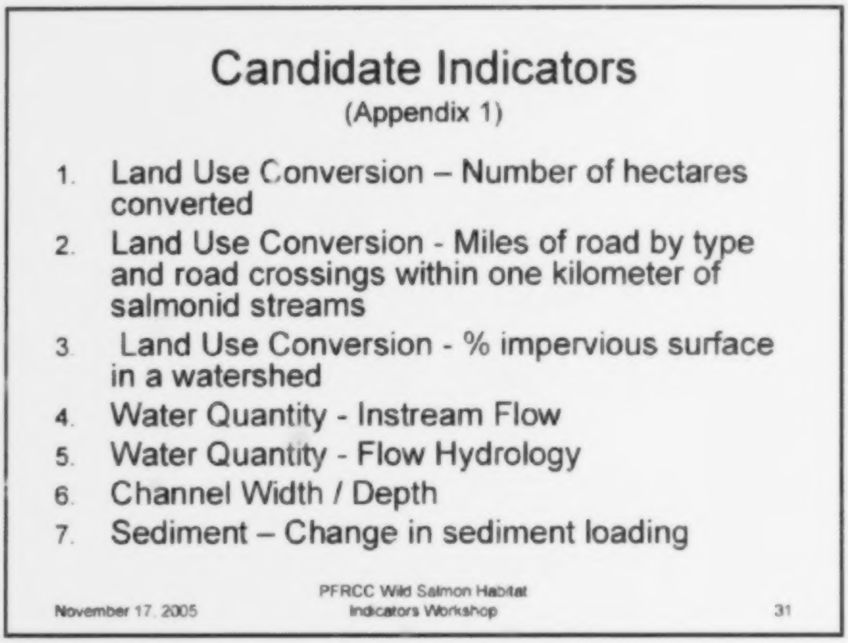
Direct / Indirect Indicators

- **Direct Habitat Indicators:**
  - Direct measures of habitat characteristics (e.g., temperature, dissolved oxygen, substrate, etc.)
- **Indirect Indicators:**
  - Include elements of disturbance to habitat (e.g., amount of land clearing)
- Concepts of Direct and Indirect Habitat Indicators are embodied on the Pressure-State-Impact-Response models discussed above



Candidate Indicators

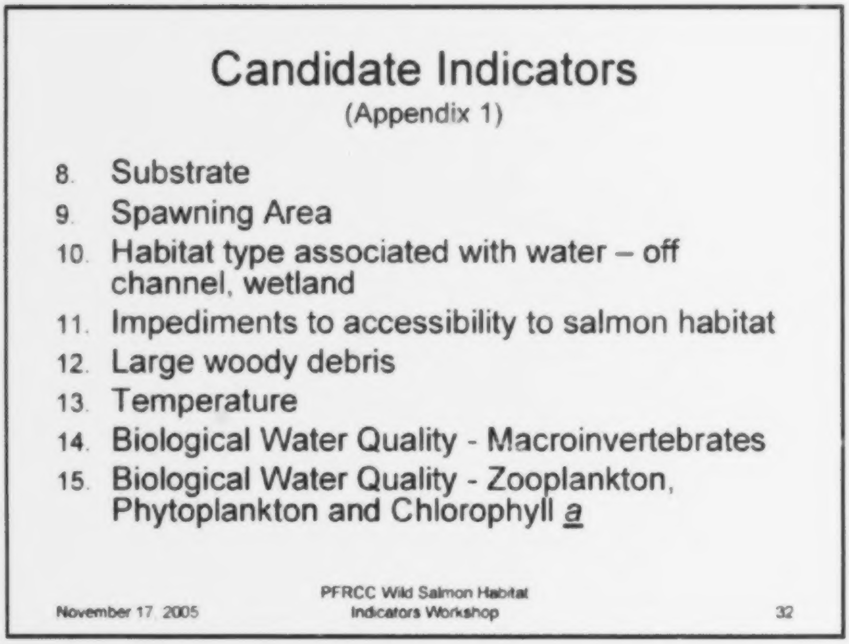
- Lists presented in Appendix 2



Candidate Indicators

(Appendix 1)

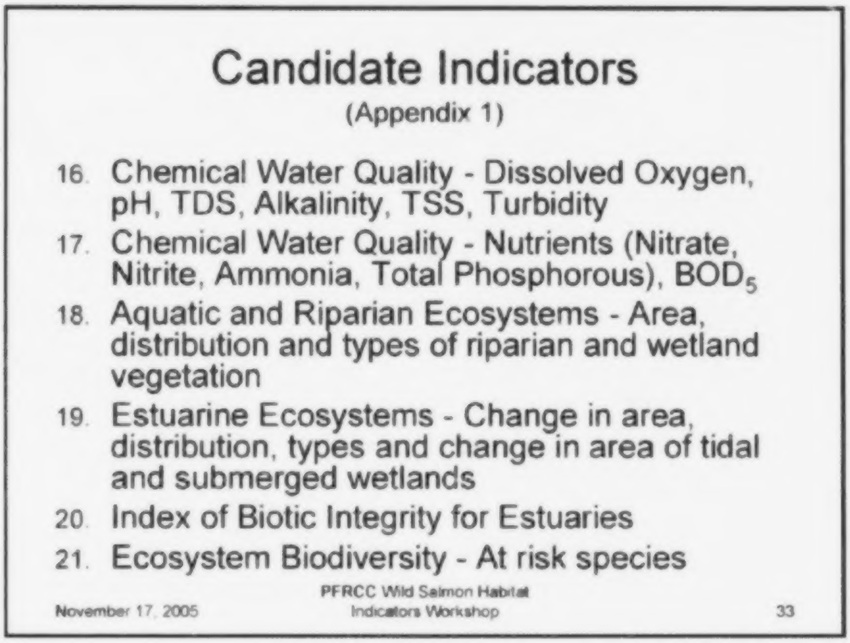
1. Land Use Conversion – Number of hectares converted
2. Land Use Conversion - Miles of road by type and road crossings within one kilometer of salmonid streams
3. Land Use Conversion - % impervious surface in a watershed
4. Water Quantity - Instream Flow
5. Water Quantity - Flow Hydrology
6. Channel Width / Depth
7. Sediment – Change in sediment loading



Candidate Indicators

(Appendix 1)

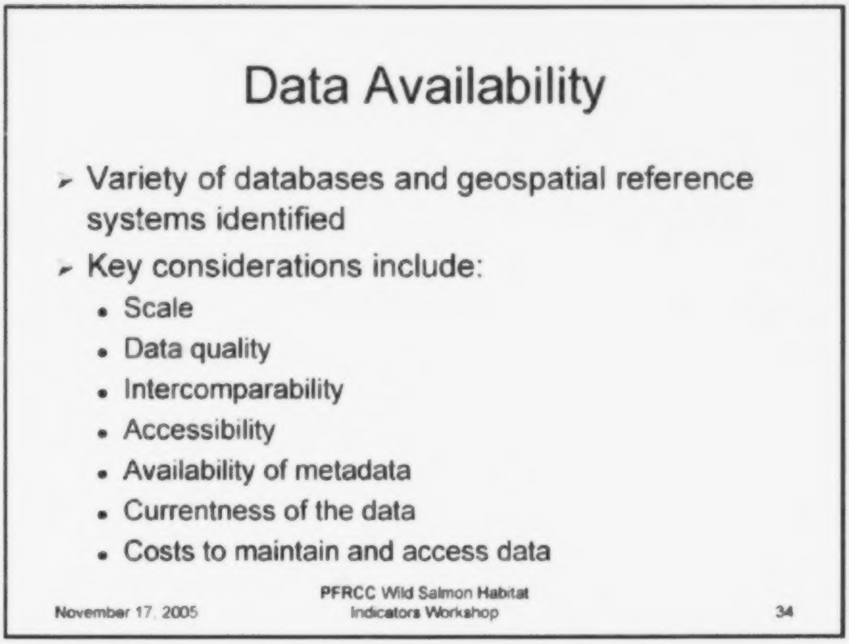
8. Substrate
9. Spawning Area
10. Habitat type associated with water – off channel, wetland
11. Impediments to accessibility to salmon habitat
12. Large woody debris
13. Temperature
14. Biological Water Quality - Macroinvertebrates
15. Biological Water Quality - Zooplankton, Phytoplankton and Chlorophyll *a*



Candidate Indicators

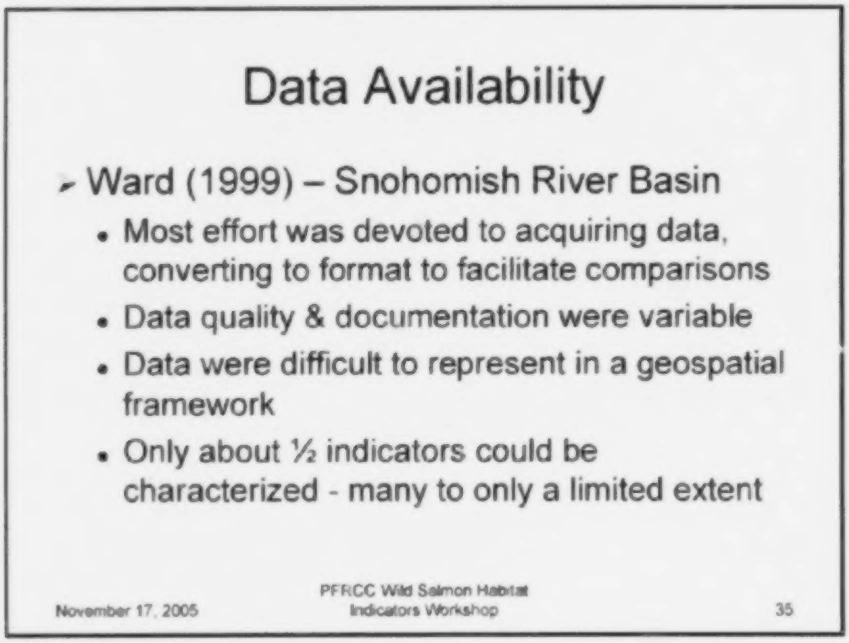
(Appendix 1)

16. Chemical Water Quality - Dissolved Oxygen, pH, TDS, Alkalinity, TSS, Turbidity
17. Chemical Water Quality - Nutrients (Nitrate, Nitrite, Ammonia, Total Phosphorous), BOD_5
18. Aquatic and Riparian Ecosystems - Area, distribution and types of riparian and wetland vegetation
19. Estuarine Ecosystems - Change in area, distribution, types and change in area of tidal and submerged wetlands
20. Index of Biotic Integrity for Estuaries
21. Ecosystem Biodiversity - At risk species



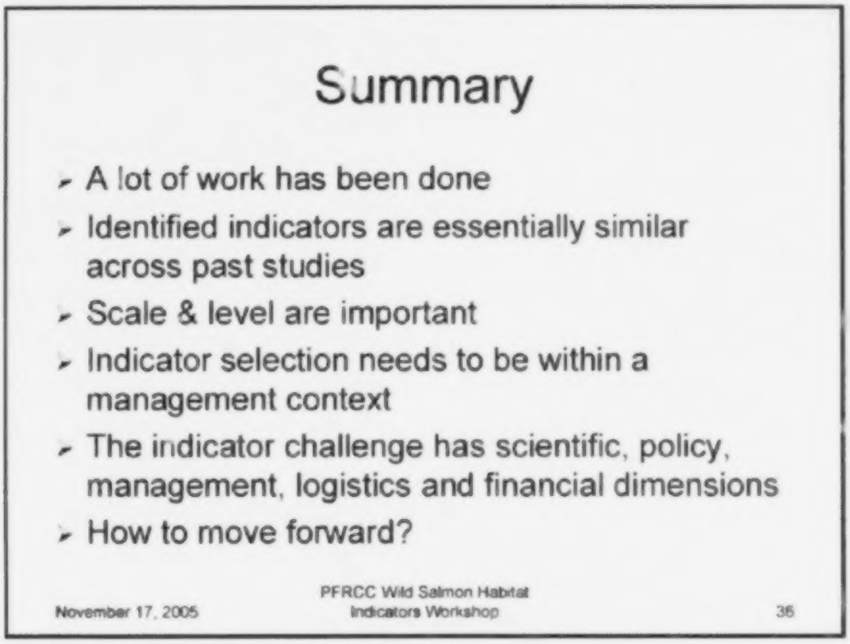
Data Availability

- Variety of databases and geospatial reference systems identified
- Key considerations include:
  - Scale
  - Data quality
  - Intercomparability
  - Accessibility
  - Availability of metadata
  - Currentness of the data
  - Costs to maintain and access data



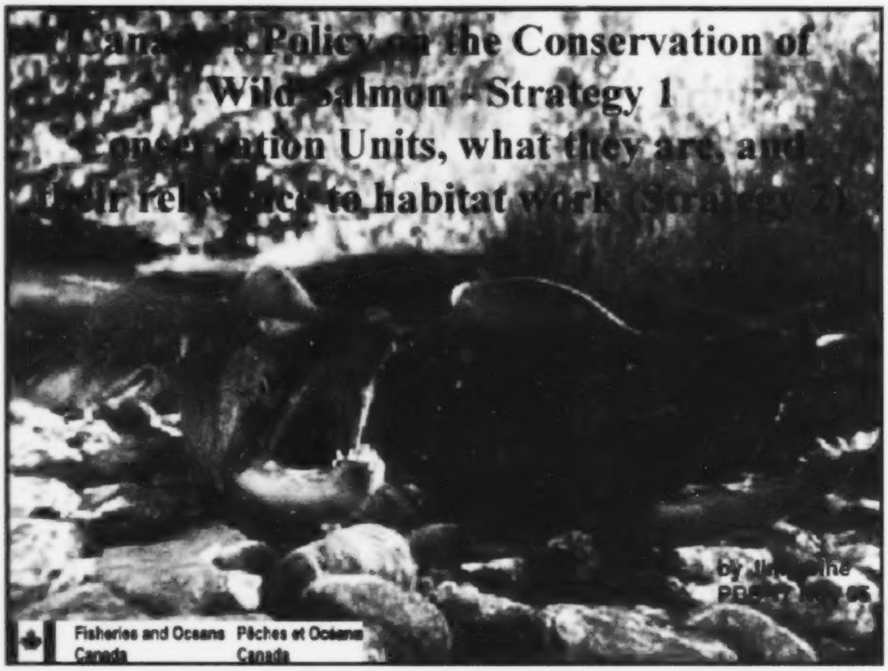
Data Availability

- Ward (1999) – Snohomish River Basin
  - Most effort was devoted to acquiring data, converting to format to facilitate comparisons
  - Data quality & documentation were variable
  - Data were difficult to represent in a geospatial framework
  - Only about ½ indicators could be characterized - many to only a limited extent



Summary

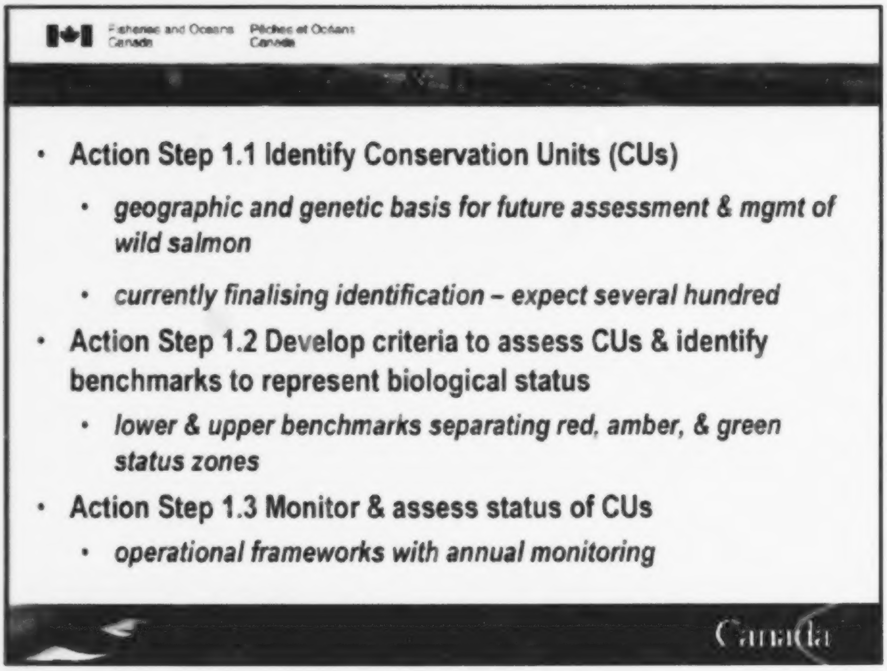
- A lot of work has been done
- Identified indicators are essentially similar across past studies
- Scale & level are important
- Indicator selection needs to be within a management context
- The indicator challenge has scientific, policy, management, logistics and financial dimensions
- How to move forward?



Canada's Policy on the Conservation of Wild Salmon - Strategy 1
Conservation Units, what they are, and their relevance to habitat work (Strategy 2)

by J[illegible]ne
P[illegible] 05

Fisheries and Oceans Canada Pêches et Océans Canada



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- Action Step 1.1 Identify Conservation Units (CUs)
  - *geographic and genetic basis for future assessment & mgmt of wild salmon*
  - *currently finalising identification – expect several hundred*
- Action Step 1.2 Develop criteria to assess CUs & identify benchmarks to represent biological status
  - *lower & upper benchmarks separating red, amber, & green status zones*
- Action Step 1.3 Monitor & assess status of CUs
  - *operational frameworks with annual monitoring*

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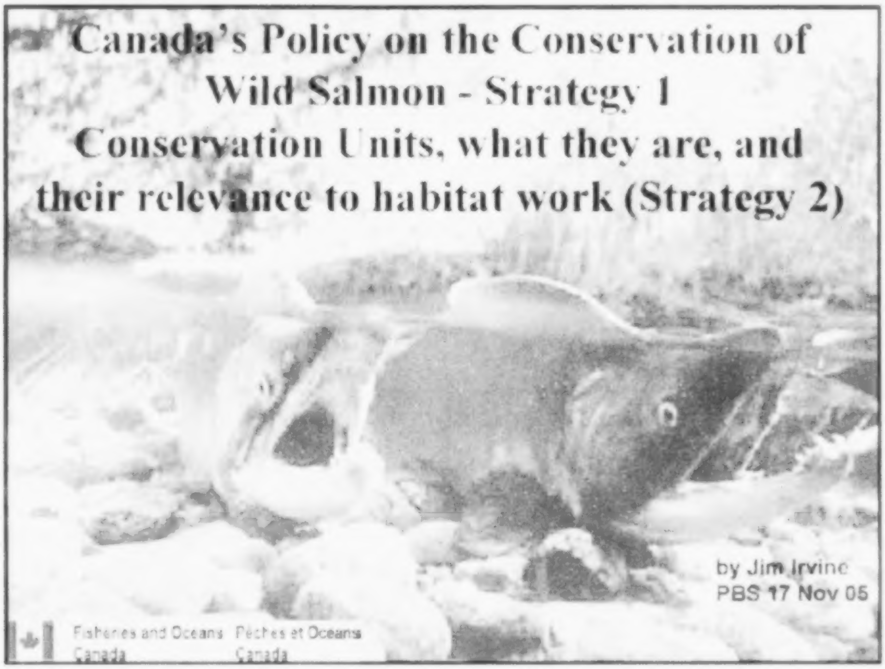
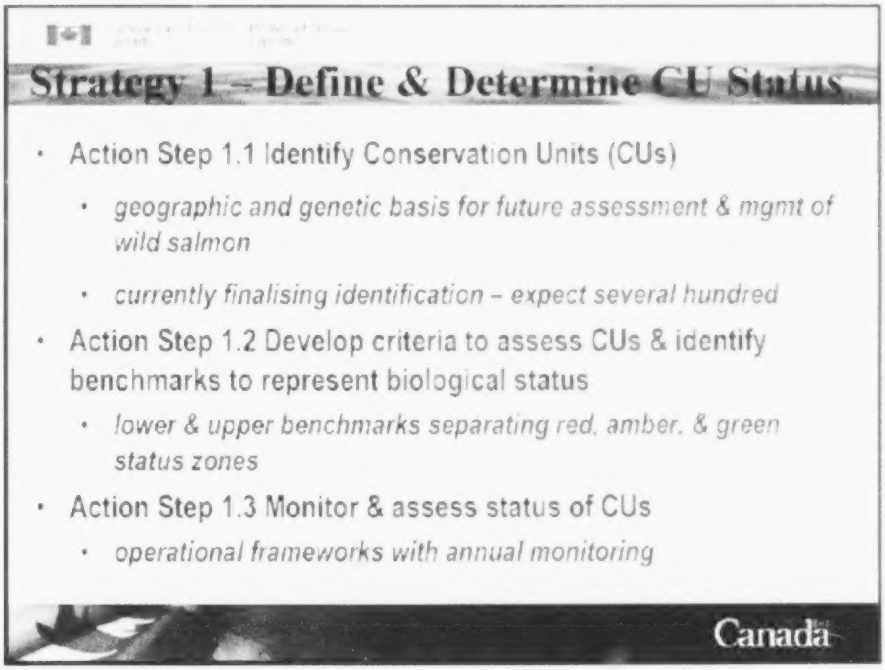


Canada's Policy on the Conservation of Wild Salmon - Strategy 1

Conservation Units, what they are, and their relevance to habitat work (Strategy 2)

by Jim Irvine
PBS 17 Nov 05

Fisheries and Oceans Canada Pêches et Océans Canada



Strategy 1 – Define & Determine CU Status

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  - *geographic and genetic basis for future assessment & mgmt of wild salmon*
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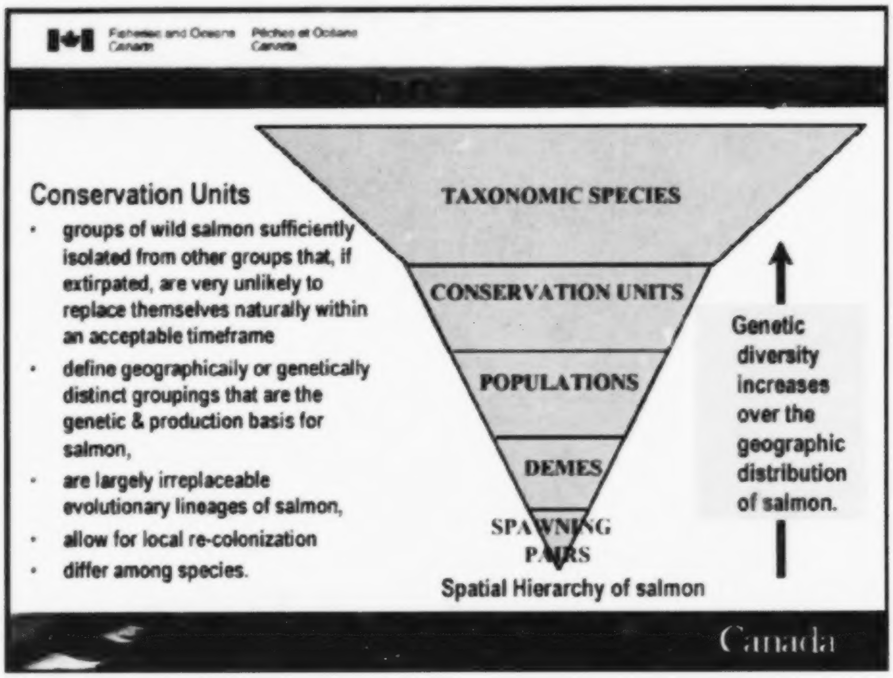
Canada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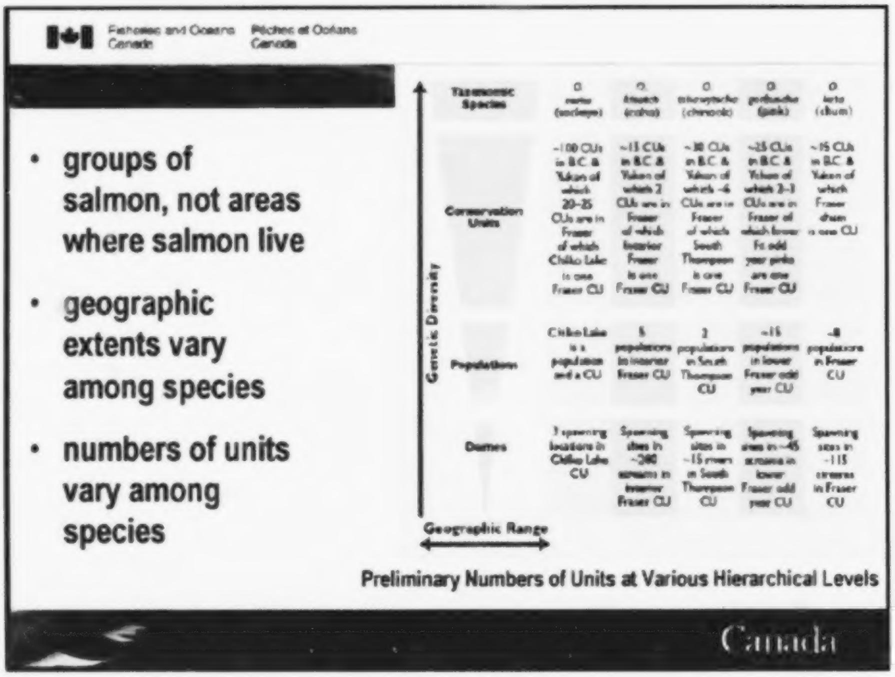
Pêches et Océans Canada
TAXONOMIC SPECIES
CONSERVATION UNITS
POPULATIONS
DEMES
SPAWNING PAIRS
Canada

Conservation Units

- groups of wild salmon sufficiently isolated from other groups that, if extirpated, are very unlikely to replace themselves naturally within an acceptable timeframe
- define geographically or genetically distinct groupings that are the genetic & production basis for salmon,
- are largely irreplaceable evolutionary lineages of salmon,
- allow for local re-colonization
- differ among species.

Genetic diversity increases over the geographic distribution of salmon.

Spatial Hierarchy of salmon


Fisheries and Oceans Canada
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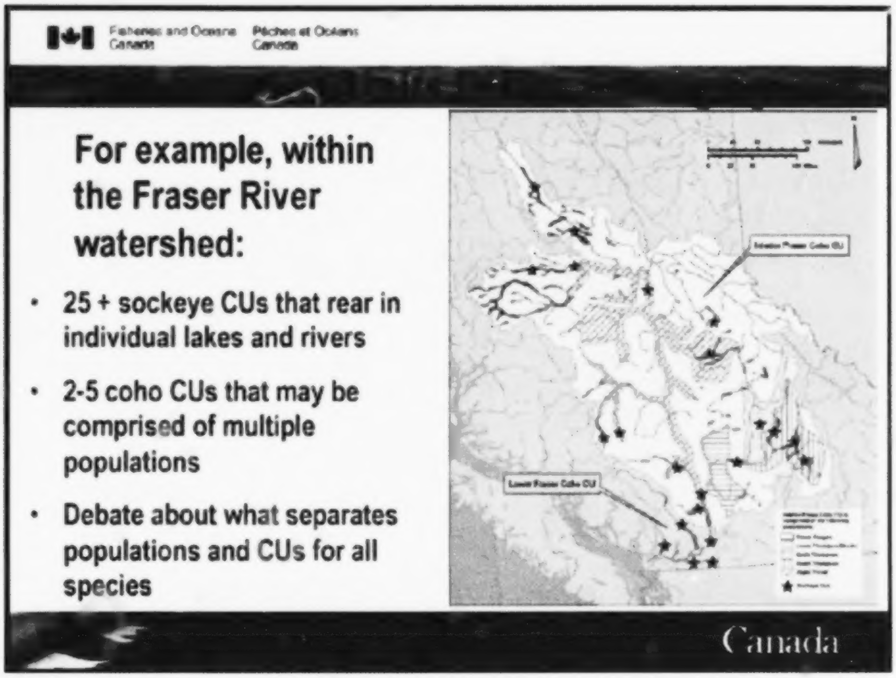
Genetic Diversity
Geographic Range
Canada

- groups of salmon, not areas where salmon live
- geographic extents vary among species
- numbers of units vary among species

Taxonomic Species	O. nerka (sockeye)	O. kisutch (coho)	O. tshawytscha (chinook)	O. gorbuscha (pink)	O. keta (chum)
Conservation Units	~100 CUs in B.C. & Yukon of which 20-25 CUs are in Fraser of which Chilko Lake is one Fraser CU	~15 CUs in B.C. & Yukon of which 2 CUs are in Fraser of which Interior Fraser is one Fraser CU	~30 CUs in B.C. & Yukon of which ~6 CUs are in Fraser of which South Thompson is one Fraser CU	~25 CUs in B.C. & Yukon of which 2-3 CUs are in Fraser of which lower Fr odd year pinks are one Fraser CU	~15 CUs in B.C. & Yukon of which Fraser chum is one CU
Populations	Chilko Lake is a population and a CU	5 populations in Interior Fraser CU	3 populations in South Thompson CU	~15 populations in lower Fraser odd year CU	~8 populations in Fraser CU
Demes	3 spawning locations in Chilko Lake CU	Spawning sites in ~200 streams in Interior Fraser CU	Spawning sites in ~15 rivers in South Thompson CU	Spawning sites in ~45 streams in lower Fraser odd year CU	Spawning sites in ~115 streams in Fraser CU

Preliminary Numbers of Units at Various Hierarchical Levels



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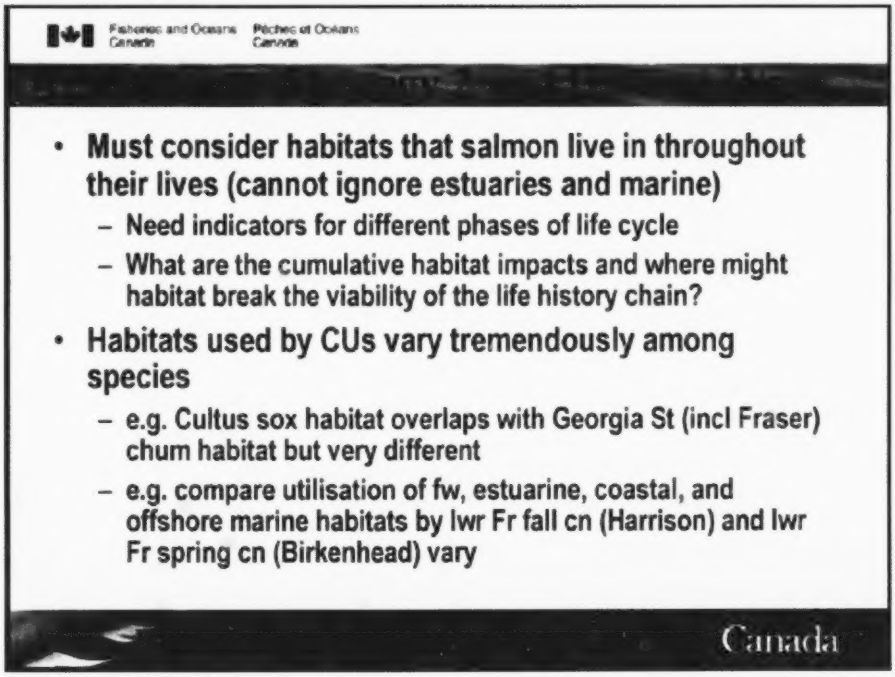
For example, within the Fraser River watershed:

- 25 + sockeye CUs that rear in individual lakes and rivers
- 2-5 coho CUs that may be comprised of multiple populations
- Debate about what separates populations and CUs for all species

Interior Fraser Coho CU
Lower Fraser Coho CU

Canada



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- Must consider habitats that salmon live in throughout their lives (cannot ignore estuaries and marine)
  - Need indicators for different phases of life cycle
  - What are the cumulative habitat impacts and where might habitat break the viability of the life history chain?
- Habitats used by CUs vary tremendously among species
  - e.g. Cultus sox habitat overlaps with Georgia St (incl Fraser) chum habitat but very different
  - e.g. compare utilisation of fw, estuarine, coastal, and offshore marine habitats by lwr Fr fall cn (Harrison) and lwr Fr spring cn (Birkenhead) vary

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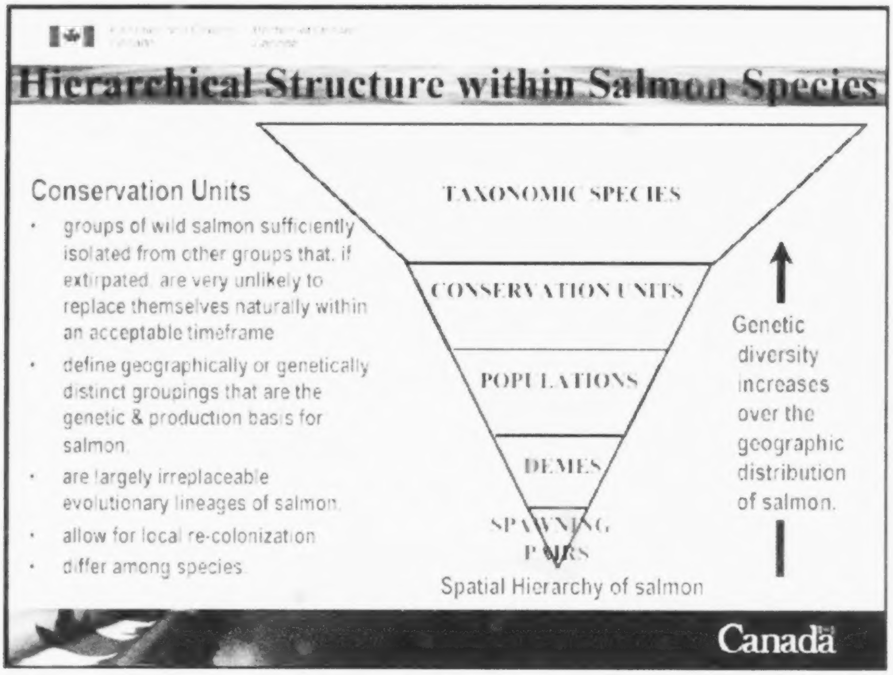

Hierarchical Structure within Salmon Species

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TAXONOMIC SPECIES
CONSERVATION UNITS
POPULATIONS
DEMES
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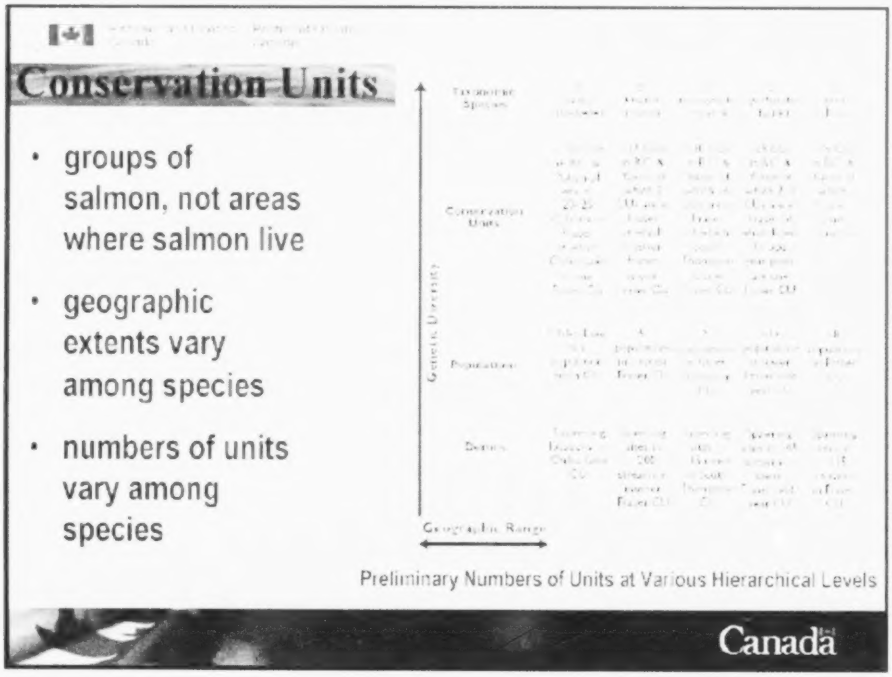

Conservation Units

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Taxonomic Species
Conservation Units
Populations
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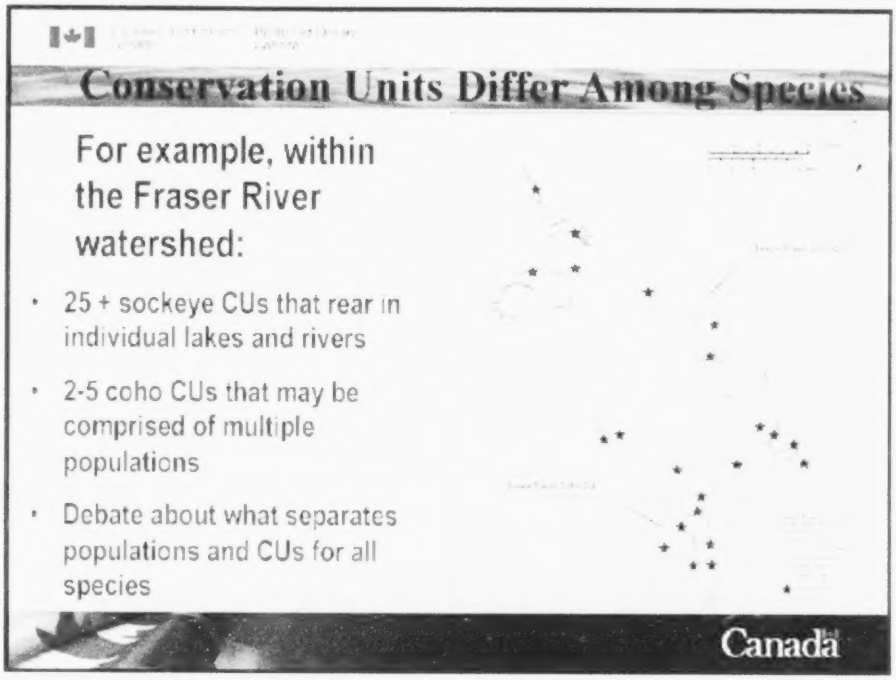
Preliminary Numbers of Units at Various Hierarchical Levels



Conservation Units Differ Among Species

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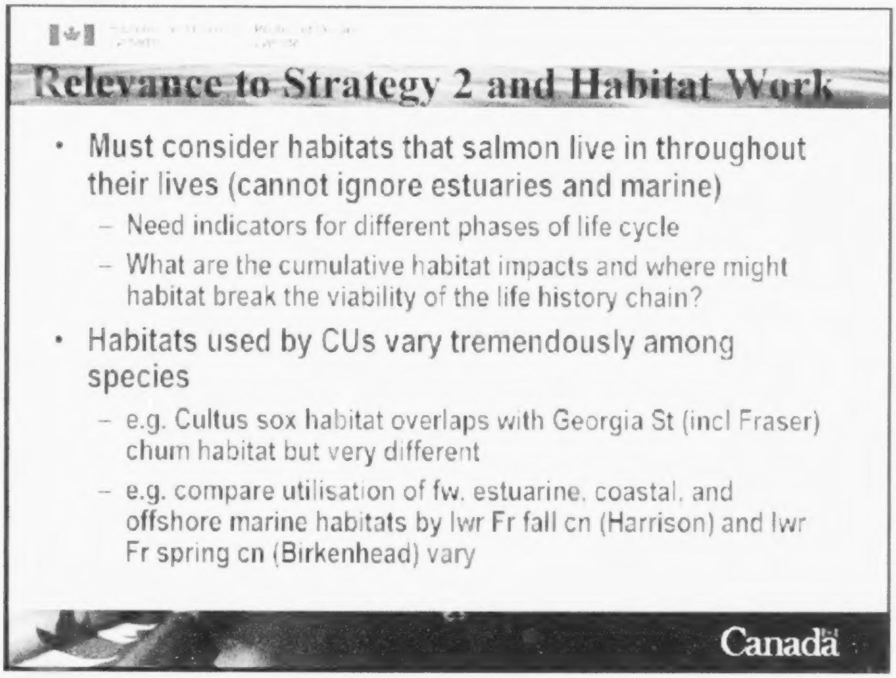

Relevance to Strategy 2 and Habitat Work

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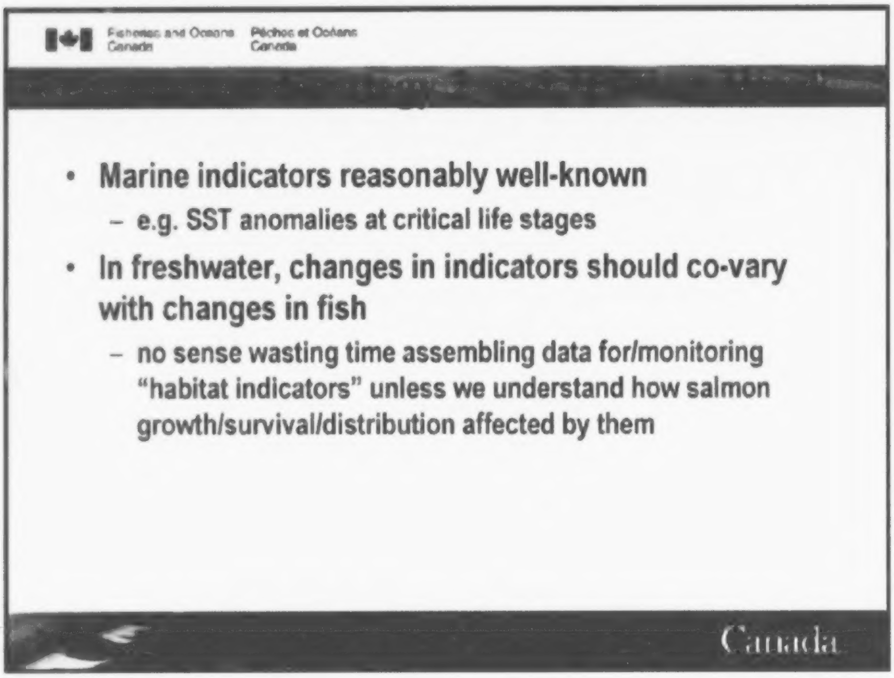

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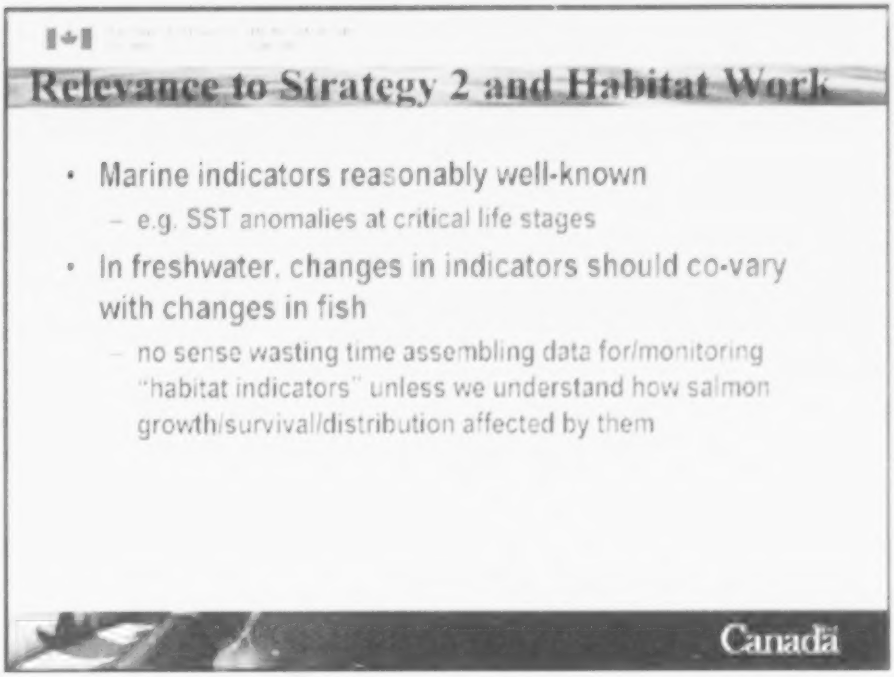
- Marine indicators reasonably well-known
  - e.g. SST anomalies at critical life stages
- In freshwater, changes in indicators should co-vary with changes in fish
  - no sense wasting time assembling data for/monitoring "habitat indicators" unless we understand how salmon growth/survival/distribution affected by them

Canada



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